UNIVERSITY OF ARIZONA
39001006963733

Industrial Management Series

McGRAW-HILL INDUSTRIAL MANAGEMENT SERIES

DEXTER S. KIMBALL, Consulting Editor

Dean, College of Engineering, Cornell University

# STANDARDS AND STANDARDIZATION

# STANDARDS
## AND
# STANDARDIZATION

BY

NORMAN F. HARRIMAN

*Senior Engineer-Physicist, National Bureau of Standards. Member (Alt.), American Engineering Standards Committee. Vice-chairman, Federal Specifications Board; Member, Federal Purchasing Board; Bureau of the Budget, United States Government. Member, American Society of Mechanical Engineers. Member, Verein Deutscher Ingenieure. Member, American Society for Testing Materials. Translator, Classen, "Quantitativen Chemischen Analyses." Author, "Principles of Scientific Purchasing." Formerly, Engineer of Tests, Union Pacific Railroad Company.*

FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK: 370 SEVENTH AVENUE
LONDON: 6 & 8 BOUVERIE ST., E. C. 4
1928

Copyright, 1928, by the
McGraw-Hill Book Company, Inc.

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

# PREFACE

The purpose in this book has been to present a concise account of the more important elements of the science and art of Standards and Standardization.

The subject of Standards has been treated only in outline and as an introduction to Standardization, the major theme of the book.

No attempt has been made to discuss, or even to mention, all of the various sections of the subject of Standardization, nor has any effort been made to treat the topics selected in an exhaustive manner. An endeavor has rather been made to select a few important elements of the subject and to treat them concisely and accurately from a scientific, technical, and economic standpoint.

Standardization has been considered more particularly in connection with manufacturing industry. The three other major branches of industry—agriculture, mining, and transportation—have been considered only incidentally. Furthermore, a discussion of standards and standardization in connection with operating conditions in manufacturing industry, such as time or motion studies, etc., has purposely been omitted as being beyond the scope of the book.

In view of the interest that has been shown in standardization in the last few years, and its present importance in all branches of industry, it seems strange that at the present time (August, 1928) there is not a single book in the English language on this important subject. It is hoped that the present endeavor will, at least partially, serve to provide for this need.

Ample references have been made to supply collateral reading for those wishing to pursue further any particular aspect of either branch of the subject.



76019

The author wishes gratefully to acknowledge the helpful suggestions which he has received from friends. The following have read the entire manuscript: General H. C. Smither, Chief Coordinator, Bureau of the Budget of the United States; Rear Admiral H. H. Rousseau (C.E.C.), Bureau of Yards and Docks, United States Navy; Captain E. L. Bennett, Assistant to Chief, Bureau of Engineering, United States Navy; and Professor Collins P. Bliss, Associate Dean, College of Engineering, New York University. Commander T. J. Keleher, Bureau of Engineering, United States Navy, read the chapter on Specifications.

Several of the author's colleagues at the National Bureau of Standards have furnished data and have read the entire manuscript, or portions of it: Dr. Paul R. Heyl, Chief, Sound Section, read the entire manuscript; Mr. E. C. Crittenden, Chief, Electrical Division, read the portion on electrical units and standards; Mr. H. W. Bearce, Co-chief, Weights and Measures Division, read the portions on units and standards of length and mass; Dr. L. V. Judson, Chief, Length Section, read the portion on length units and standards; Mr. A. T. Pienkowsky, Chief, Mass Section, read the portion on units and standards of mass; and Dr. W. W. Coblentz, Chief, Radiometry Section, read the portion on radiation. The author wishes particularly to acknowledge his obligation to Mr. H. D. Hubbard, Assistant to the Director, National Bureau of Standards.

The author is indebted to Mr. W. A. Austin, Consulting Engineer, Baldwin Locomotive Works, for special assistance; to Dr. E. L. Baer, Secretary of the German Embassy, for data on standardization work in Germany; to Dr. P. G. Agnew, Secretary of the American Engineering Standards Committee, for data on foreign standardizing bodies; to Mr. D. A. Steel, Purchases and Stores Editor, *Railway Age*, for constructive criticisms; to the Ford Motor Company, for data on Johannson gage blocks and details of inspection work in the factory of the Lincoln Motor Company, a subsidiary of the Ford Motor Company; and to Colonel T. C. Dickson, Commanding Officer, Watertown Arsenal, War Department, for data on X-ray inspection work in the War Department.

Acknowledgment is made to the publishers of *Railway Age*, *Forbes Magazine*, and *Industrial Management*, for permission to use material from articles which the author had published in those periodicals.

Acknowledgment is also made to all of the works cited in the Bibliography, to the Transactions of the American Society for Testing Materials, to the various publications of the National Bureau of Standards, and to the Annual Reports of the Director. All of these have been freely used.

NORMAN F. HARRIMAN.

WASHINGTON D. C.
*August*, 1928.

# CONTENTS


PAGE

PREFACE . . . . . v

INTRODUCTION . . . . . xv

CHAPTER I

EVOLUTION OF STANDARDS, INDUSTRY, AND STANDARDIZATION . . . 1
Origin of Standards . . . . . 1
Evolution of Industry . . . . . 3
Handicraft Production . . . . . 3
Gilds . . . . . 4
The Cottage Period . . . . . 4
The Factory Period . . . . . 6
Three Important Modern World Epochs . . . . . 6
The Renaissance . . . . . 7
The Reformation . . . . . 7
The Industrial Revolution . . . . . 7
Development of Electrical Machinery . . . . . 9
Development of the Internal-combustion Motor . . . . . 11
Sources of Energy . . . . . 11
Recent Application of Standardization . . . . . 12
Advances in the Industrial Arts . . . . . 13
Advances of Standardization in Industry . . . . . 14
Importance of Transportation and Communication Facilities . . 15
Standardization a Useful Servant, but a Bad Master . . . . . 19
Modern Period in Industry . . . . . 19
Recent Developments in Business . . . . . 20

CHAPTER II

STANDARDS . . . . . 23
Standards of Measurement . . . . . 24
Purpose of Standards of Measurement . . . . . 25
Kinds of Units . . . . . 26
Units and Standards . . . . . 28
Units and Standards of Length . . . . . 30
Units and Standards of Mass . . . . . 36
Distinction between Mass and Weight . . . . . 41
Unit and Standard of Time . . . . . 43
Units and Standards of Heat and Temperature . . . . . 47

PAGE
Units and Standards of Electrical Resistance . . . . . 50
Unit of Electrical Current . . . . . 51
Unit and Standard of Electrical Pressure . . . . . 51
The Metric System in Science and Industry . . . . . 54

## CHAPTER III

STANDARDS (*continued*) . . . . . 55
Standard Constants . . . . . 55
Purpose of Standard Constants . . . . . 55
Standards of Quality . . . . . 59
Purpose of Standards of Quality . . . . . 60
Standards of Performance . . . . . 61
Purpose of Standards of Performance . . . . . 62
Industrial Application of X-rays . . . . . 64
"Streamline" Designing Based upon Scientific Tests . . . . . 69
Control of Railway-track Scales . . . . . 72
The Value or Utility of a Machine Depends upon Performance . . 72
Standards of Practice . . . . . 74
Purpose of Standards of Practice . . . . . 74
Importance of Standards to the Purchaser and Consumer . . . . 76

## CHAPTER IV

STANDARDIZATION, GENERAL CONSIDERATIONS . . . . . 78
Application of Standardization . . . . . 80
Compulsory Standardization of Weights, Measures, Money, etc . . 81
Voluntary Standardization . . . . . 81
Advantages of Standardization . . . . . 85
Object of Industrial Standardization . . . . . 86
Modern Industry Based upon Standardization . . . . . 89
Mass Production . . . . . 91
Difficulties of Standardization . . . . . 92
Classification of Standards by Use . . . . . 95
Industrial Rationalization—The Elimination of Waste . . . . . 96
Economic Importance of Standardization . . . . . 97
Systematizes Business . . . . . 99
Better Serves the Producer . . . . . 100
Better Serves the Consumer . . . . . 102
Various Aspects of Standardization . . . . . 102

## CHAPTER V

STANDARDIZATION, PARTICULAR CONSIDERATIONS . . . . . 104
Relations between Men, Methods and Products . . . . . 104
The Human Element . . . . . 104
Materials . . . . . 105
Methods . . . . . 106

PAGE
Product . . . . . 106
Uses . . . . . 108
Standardization of Nomenclature . . . . . 108
Standardization of Variety, or Simplification . . . . . 111
Standardization of Variety by the War Industries Board . . . . 112
Preferred Numbers in Simplification . . . . . 115
Unlimited Variety Expensive for Consumers . . . . . 115
Preferred Numbers in Simplification . . . . . 116
Standardization of Dimensions . . . . . 117
Standardization in Manufacturing . . . . . 122
Standardization—Bane or Blessing? . . . . . 126

## CHAPTER VI

STANDARDIZATION OF QUALITY, SPECIFICATIONS . . . . . 129
Object of Specifications . . . . . 130
Specifications *vs.* Brands, Trade Names, Standard Samples, etc . . . . . 132
Use of an Acceptable List of Approved Commodities in Purchasing . . . . . 134
Commodities Should Be Tested for Compliance with Specifications 135
Desirability of Purchasing on Performance . . . . . 136
The Writing of Specifications a Progressive Art . . . . . 142
Requirements of a Specification . . . . . 144
The Preparation of Specifications . . . . . 144
Conclusions in Regard to the Formulation of Specifications . . . 146
Precepts for Specification Writers . . . . . 151
Advantages of Using Specifications . . . . . 151
Reduction in the Number of Items of Materials and Supplies Used . . . . . 151
Interpretation of Requirements . . . . . 152
Test Methods . . . . . 153
Competitive Bids . . . . . 153
Knowledge of Materials . . . . . 153
Production . . . . . 153
Sales . . . . . 153
Deliveries . . . . . 154

## CHAPTER VII

NATIONAL STANDARDIZING BODIES . . . . . 155
American Engineering Standards Committee . . . . . 156
British Engineering Standards Association . . . . . 164
Deutscher Normenausschuss . . . . . 171
Organization and Procedure . . . . . 171
Publication of Standards . . . . . 174
Association Française de Normalisation . . . . . 181

PAGE
American Society for Testing Materials . . . . . 183
International Standardizing Bodies . . . . . 184
International Electrotechnical Commission . . . . . 184
International Commission on Illumination . . . . . 186
Proposed International Standardizing Body . . . . . 186

## CHAPTER VIII

INTERNATIONAL AND NATIONAL STANDARDIZING LABORATORIES . . . 187
Bureau International des Poids et Mesures . . . . . 187
Early Foreign National Standardizing Laboratories . . . . . 190
Physikalisch-Technische Reichsanstalt . . . . . 190
Staatliche Materialprüfungsampt . . . . . 191
National Physical Laboratory . . . . . 191
Board of Trade Standards Department (British) . . . . . 192
Laboratoire d'Essais . . . . . 192
Laboratoire Central d'Électricité . . . . . 193
National Bureau of Standards . . . . . 194
Electricity Division . . . . . 200
Weights and Measures Division . . . . . 200
Heat and Power Division . . . . . 201
Optics Division . . . . . 201
Chemistry Division . . . . . 202
Mechanics and Sound Division . . . . . 202
Organic and Fibrous Materials Division . . . . . 203
Metallurgy Division . . . . . 203
Clay and Silicate Products Division . . . . . 204
Commercial Standards Group . . . . . 204
Other National Standardizing Laboratories . . . . . 205

## CHAPTER IX

TREND OF STANDARDIZATION . . . . . 207
Recent Activity in Standardization . . . . . 209
Development of Standards of Quantity and Quality . . . . . 210
Relation of Research to Standards and Standardization . . . . . 211
Trend in Quality Standards . . . . . 218
A Look into the Future . . . . . 218

## APPENDIX

STANDARDIZATION AND COORDINATION OF GOVERNMENT PURCHASES 220
Organization and Procedure of the Federal Specifications Board . . . . . 221
Extent of Board's Authority . . . . . 223
Economy of Using Standardized Purchase Specifications . . . . 224
Interdepartmental Board of Contracts and Adjustments . . . . 225
Contracts Standardized . . . . . 225

PAGE
Federal Purchasing Board . . . . . 227
Coordinator for Purchase . . . . . 228
Inspection . . . . . 231
Coordination of Purchasing Activities . . . . . 231
Standard Form for Specifications . . . . . 232
Sample Specification . . . . . 235
Technical Committees of the Federal Specification Board . . . 241
Cooperation in the Selection of Master Specifications . . . . . 242
Bibliography . . . . . 243

INDEX . . . . . 247

# INTRODUCTION

Standardization, in a sense, is the bed-rock of civilization. By it the conduct and morals of the individual are made to conform to certain rules set by the community and he who rejects these standards becomes an outlaw.

Thus the general subject is one of greatest importance and as industry is now the prime mover in the advance of civilization, a special study of its application thereto becomes eminently fitting.

It is peculiar that, in spite of its major importance, the subject seems to have been overlooked in literature. We have no considerable writings on standardization; merely the recorded recommendations of technical associations and some slender effort in the unification of business forms.

So far as I am at present advised, no previous attempt has been made to discuss the subject in its broader modern sense, and Mr. Harriman's treatise is thus a notable endeavor to bring standardization nearer to its proper place as an exact science.

He is happy in a quotation from the philosopher Descartes, who wrote, three hundred years ago, that—"there is seldom so much perfection in works composed of many separate parts, upon which many different hands have been employed, as in those completed by a single master."

Standardization, properly directed becomes, in modern industry, the "single master" that controls in perfection, that product which, by the dictates of present mass production, must needs be the work of "many hands."

Industry, having accepted this master, would do well to codify its teachings, and it is to this end that Mr. Harriman's book is of most practical value. His present connection with the National Bureau of Standards and his long experience as a testing engineer fit him eminently for the task he has undertaken.

With the analytic instinct of the true engineer he arranges his subject in logical sequence and under convenient caption. First are described the present accepted standards of measured value and the instruments necessary to maintain their exactness.

The needs for standard nomenclature are stressed because "these enable purchaser and producer to use and understand the same language." Under the caption "Standardization of Variety," an impressive mass of evidence is set forth to show the economies already achieved by simplification of types, while the rewards for future effort in the same direction are clearly forecast.

As never before in the history of mankind, the World War brought to realization the necessity for standards in mass production and the practical adaptation of these standards to industry. To this end, "dimensional standardization" and the need for universal codified tolerances in mechanical operations can be considered not the least important message that the book conveys.

The author is not insensible to the dangers of over-standardization and stresses the point that accepted standards must be flexible enough to adjust themselves to progress.

But why delay the reader? The subject is so interesting and so full of future promise that the book itself is its own best reviewer.

Introductions to interesting works should be like those to interesting personalities:—the platitudes of the introducer should not be of such length as to fatigue the waiting audience.

And so, in introducing "Standards and Standardization," I recommend to the careful attention of its readers, a thoroughly practical and understandable treatise on a subject increasingly important in modern industry.

SAMUEL M. VAUCLAIN,
*President*, Baldwin Locomotive Works.

PHILADELPHIA, PA.
*July* 31, 1928.

# STANDARDS AND STANDARDIZATION

## CHAPTER I

### THE EVOLUTION OF STANDARDS, INDUSTRY, AND STANDARDIZATION

The origin of standards goes back, historically, to the crude beginnings of human culture. In ancient times, community life was governed by customs and common rules administered by the head of the group of people, which gave rise to the first standards of life: the family, common speech, picture writing and phonetic symbols, primitive clothing and shelter, religion, laws, division of time, etc.

With the beginning of these groups of people and the production of articles of common use and their barter and exchange, the need of prescribed rules of action, definite forms and sizes of articles, money, and weights and measures became apparent. Such *standards* may be found in all times and among all peoples, and with advancing culture, their number increases.

Weights and measures must have been among the earliest needs of civilized life. The earliest systems of weights and measures of which we now have any knowledge were those of Assyria, Babylonia, Chaldea, and Egypt. Of these early systems, the Egyptian has probably had the greatest influence upon those of other countries. It is generally admitted that the Egyptian

systems of weights and measures passed into Asia, Judea, and Greece, and with some modifications extended to Italy, where it was adopted by the Romans and subsequently by all European nations.

The English units of measures of length, capacity, and weight—the yard, bushel, and pound (avoirdupois and troy) —now in use for commercial purposes in the United States and in Great Britian and its colonies, have come down to us from the Saxons, though some modifications of the bushel and pound have since been made.

The metric system of weights and measures may justly claim preeminence over all others, as a system based on strictly scientific principles, and it is now in practically exclusive use in all civilized countries except the United States and Great Britian and its colonies, and even in these countries it is used in all scientific work.

In a similar manner, "money," or a standard *medium of exchange*, has been in use since primitive times. Money consists of articles of wealth and property rights which are generally acceptable in exchange: cattle, slaves, wheat, corn, tobacco, gold dust, furs, ivory, and many other things have been so used. The civilized world has quite generally adopted gold and silver as the base of *money*, owing to their scarcity and natural adaptability. These metals originally passed from hand to hand simply by weight. Later, coinage, or the governmental certification of weight and fineness of precious metal money units, was developed. There are also several kinds of token and paper money which are used *interchangeably* in business transactions.

Money is not only the standard medium of exchange, but it is also the standard of *value*. Since most exchanges are based upon money as a medium, most properties and services are, at some time or other, compared with money, and their values are usually stated in terms of money, *i.e.*, as *prices*.

**Evolution of Industry.**

The first main step in *industrial evolution* was what is called the *family* or *household* system. At this stage, articles were made in the household for use by the members thereof, from raw materials produced by them. Several modern industries have developed from such beginnings, for example: spinning of threads and yarns and weaving of fabrics; knitting; tanning; making leather products, such as footwear, harness, belting, etc.; making furniture, carpets and rugs; making clothing of fabrics or leather; making soap; canning of food; butchering and making meat-food products; laundering; milling; baking; etc.

In its original form, on the very frontiers of civilization, the domestic system was entirely devoid of exchange. Under it, each family or household, with a few inevitable exceptions, provided for all of its own wants. Even here, of course, there was some differentiation, the natural and obvious division of labor between members of the same household.

Vestiges of domestic production, the first chronologically, still persist on a small scale in remote communities where the wants of the people are simple and easily taken care of. There is no place at present in the civilized or semi-civilized world, however, where the wants of any household are entirely supplied by the domestic system.

**Handicraft Production.**

The next step in this evolution was handicraft production, carried on either within or without the home, and it was characterized by what is now termed *custom* production. The handicraft worker usually worked directly for the consumer of his product, the region of the sale being local. The products of these craftsmen might have been bartered for the products of another craftsman, or an actual sale might have occurred based upon

the then current medium of exchange. Modern survivals of this class of production are the *custom tailor* and the *custom bootmaker.*

This step was marked by the general application of the principle of differentiation. A worker specialized on some particular line of work; he became a woodworker, a woolworker, a metalworker, a leatherworker, a stoneworker, etc. He no longer supplied *only* his own needs but lived largely by exchanging his products for those of other people. Survivals of this type may be found nowadays in the *artist* or the *village blacksmith,* working as his own master and disposing of his own product. The transition from domestic production to handicraft production was very gradual and in Europe took place in the Middle Ages.

### Gilds.

The development of the handicraft system was accompanied in the twelfth century by the growth of gilds or associations of workers in the same trade, banded together for mutual protection. The gild gave particular attention to the needs of the consumer in such matters as quality.

About the fifteenth or sixteenth centuries, the gilds began to weaken in importance, in part because of the growth of trade due to the development of capital and the extension of business and exploration. The necessity of increased production, due to broadened markets, overcame the power of the gilds, and the *organizer* began to appear in industry.

### The Cottage Period.

In this period, the master workman who had accumulated some capital bought raw material and distributed it to workers in the country and on the outskirts of towns, later collecting the finished product and selling

it either directly to the consumer or to merchants in the towns.

Communication by road soon improved, security was greater, and the market wider. The craftsmen had begun to congregate in towns, and the broad differentiation between towns and country, between manufacture and agriculture, had become apparent. The towns themselves were, to some extent, beginning to specialize on different products and exchange with one another locally and with towns accessible by water and road transportation. A little later, differentiation had become more complex and the crafts more numerous by subdivision. They were no longer simply metalworkers, but had become cutlers, armorers, and so forth, each performing a distinct kind of metalwork. In a similar manner, they were not simply woolworkers, but were divided into spinners, weavers, and dyers, each working at a separate stage of the preparation of the wool for use in a garment. Traces of the method can be found in nearly all handicraft production, almost from the dawn of civilization. The little manufacturing that was allowed to be done in the American Colonies prior to the American Revolution was of the cottage type.

At this stage, the individual craftsman put into each article he made more or less of his creative ability. It was not until *repetition work* by hand and machine was developed that parts of articles began to approximate the same form and dimensions. Many years elapsed, however, before it became recognized that the *interchangeability* for parts of articles was a real aid in the reduction of the cost of manufacture.

The development of the same idea naturally led to that of mass or quantity production, by means of which articles can be made at less cost per unit than if they are made in small quantities. The desirability of interchangeability of parts led to the idea of *standardization*

not only of materials in general, but of the component parts and complete units of articles. It is seen, therefore, that the principles, procedures, and processes of standardization have been developing for many years.

### The Factory Period.

In the sixteenth, seventeenth, and early part of the eighteenth centuries, the cottage stage of production developed into the factory system. This system received, during the close of the eighteenth century, a great impetus from the invention of four great machines for the textile industry. Hargreaves' *spinning jenny*, patented in 1770, but in use for several years before, was the first machine to spin yarn. This was improved, in 1771, by Arkwright by the invention of his *water frame*, which was so called because it was run by water power. In 1779 Crompton constructed his *mule*, so called because its construction embodied features of both previous inventions. Textile machinery had now secured a fair start and the next step was the invention of the *power loom* by Cartwright. All of these inventions served to revolutionize the textile industry, and placed it on a machine basis. It is thus seen that the textile industry served as the basis for much of our modern standardization and mass production.

The first American to utilize the principle of standardization in manufacture was Eli Whitney, the inventor of the cotton gin, who applied it in the manufacture of firearms.

### Three Important World Epochs.

There are three outstanding epochs in the history of the modern world: *the Renaissance*, the *Reformation*, and the *Industrial Revolution*. The renaissance was primarily a *cultural* movement, the reformation a *social* movement, and the industrial revolution an *economic* movement.

These three epochs are closely interrelated in moods, motives, and methods of culture, society, and industry, and they overlap and gradually merge into the general fermentation of ideas of the time, as there is no sharp line of demarcation between the twilight of one epoch or age and the dawn of another.

### The Renaissance.

During the renaissance there was a great development of trade throughout western Europe. Commerce had pretty much disappeared with the decline of the Roman roads. When commerce began to revive, it encouraged a revival in industry. Modern inventions began to appear. Explosives were discovered which did away with armor, bows and arrows, and spears; and firearms were developed. The printing press was invented, which facilitated the dissemination of knowledge. The compass was discovered and perfected, with the result that navigation was made safer and more certain. Arabic numerals were now used in place of the awkward system of using Roman letters for expressing numbers. These inventions helped to revolutionize the world.

### The Reformation.

Overlapping the period of the renaissance was the period of the reformation, which, as commonly understood, means the religious and political revolution of the eighteenth century. It dealt almost exclusively, however, with the social, financial, educational, industrial, and general moral problems of the day.

### The Industrial Revolution.

By far the most important epoch for our present study is the *industrial or economic revolution,* preceded and accompanied by what may be termed the *mechanical revolution,* which began in England with the invention of

the steam engine, and its application at first, to machinery to pump water out of the coal mines. Later on, the new mechanical power was applied to machinery in the manufacture of iron, and in other industrial processes and uses, especially the primitive steamboat and locomotive. Modern steam locomotives, marine and stationary reciprocating steam engines, and steam-turbine power units, are the latest stage of evolution of this great invention.

Changes in steam power plants are coming rapidly, and the reciprocating steam engine is being replaced by *steam-turbine* units, higher and higher steam pressures being used. The limit of development of our present stoker-boiler-turbine type of power plant is nearly reached, and some revolutionary development is so sure to come that higher and higher allowances for depreciation and obsolescence of equipment should be made.

The laws of thermodynamics show that more power can be derived from steam if the range of temperature through which it is used is increased. A knowledge of the properties of materials at high temperatures has made possible operations at about 700°F., and 3,200 pounds pressure, and such an experimental plant is now in operation in England. At about this pressure and temperature, water reaches a critical point and passes into steam without violent boiling.

It has been proposed by the General Electric Company to combine a mercury-vapor turbine with a steam turbine, and such a combination is now being tried out. The mercury turbine utilizes the thermal energy at the high-temperature levels, and its condenser acts as a boiler to furnish steam for the steam turbine.

From the time of the entrance of the steam engine into industry, the trend was steadily toward the replacement of muscle power with *machinery* and *brain power*. Similarly, inventions in metal cutting, the slide rest for

accurately guiding cutting tools, the turret and the combination of these two elements into the automatic lathe by an American at about this time were epoch making in their importance. The evolving science of metallurgy furnished improved metals and alloys for machine construction; other structural materials were being studied; ceramics, textiles, and all of the ramifications of modern technology were being developed.

Manufacturing in the United States began on a considerable scale early in the nineteenth century. During the small factory period, patterned essentially on European lines, there were relatively narrow markets. These markets were broadened during the first half of the nineteenth century by improved transportation facilities, but national distribution could not yet be attempted. In this early period, manufacturing had not come to be thought of as involving much art or science, but was regarded more as a vocation. Utilization of scientific methods had not begun, and modern *accounting methods* and *management control* were not dreamed of.

At this stage of the development of manufacture, the need for purely manual skill had declined and it was more a matter of developing the dexterity of the human operator so as to facilitate the continuous operation of *highly specialized machines*. Industrial progress consisted largely, therefore, in the continuous advance towards a greater degree of standardization and mass production. Industrial operations were made as uniform as possible and reduced to routine; they were subdivided as far as could be into their component parts, and each part was taken care of by a special machine.

**Development of Electrical Machinery.**

The second stage in the mechanical revolution began with the application of electrical science to industrial

uses. The invention and development of the steam engine helped to revolutionize industry, but the development of electrical machinery created real industrial power. The use of electricity for lighting, manufacturing, transportation, and communication by telegraph, telephone, and radio has resulted in the formation of one of our great basic industries.

Before the advent of the electrical art, energy developed by the steam engine or falling water could be transmitted only by mechanical means through belts, shafting, gears, etc. Necessarily, the area possible to be served by a power unit was limited, and the results *uneconomic.* In the case of water power, men and materials had to be transported to the source of energy before it could be utilized; in the case of the steam engine, either the power plant, men and materials had to be transported to the cheap fuel, or the cost of the energy became excessive, due to the high cost of its transmission.

The conversion of energy into electricity through the results of modern science has made it possible to transmit energy from the place of cheapest production to the place of most economic use, and the application of electricity to the varied industrial and domestic uses has been greatly accelerated by the introduction of many *standardized electrical machines and appliances.*

Recent developments of the superpower combinations have just completed a 3,000-mile chain in the form of a rough triangle from Boston to Chicago to Pensacola, connecting the hydroelectric power resources of the South and the steam-electric plants of the North. This will make for a balancing of load between *hydroelectric* and *steam-electric* plants, and will tend to equalize the peak loads as well as to reduce the current costs per unit. Coal will be conserved, and a smaller power-plant investment will be required for a given service. This

*power pool* represents an aggregate of 10,000,000 horsepower. There are other examples of interconnected power systems in the United States.

### Development of the Internal-combustion Motor.

The third stage in the mechanical revolution was the development of the *internal-combustion motor*, which has been developed to such a high degree of refinement for lightness, efficiency, and reliability that, in one generation, it has revolutionized civilized life. It has resulted in the great automotive industry, the best example in this country of intensive mass production, based upon standardization. Authorities in the automotive industry have estimated that standardization in that industry alone has resulted in an annual saving of $750,000,000.

The motor truck and motor bus bid fair to become economical auxiliaries to all-rail transportation. It now seems probable, if not certain, that the railways will be compelled to combine airplane, motor-bus, and motor-truck transportation with train transportation. Travel by train at night, and by airplane by day, for long trips is now being introduced, and the use of the motor bus for short passenger trips, and the motor truck for short shipments of light freight, mail, or express, is increasing rapidly.

The remarkable achievements now being attained by the airplane, dirigible, submarine, Diesel or gas-electric railway locomotive, Diesel stationary power units, and the tractor are made possible by the refined development of the internal-combustion motor.

### Sources of Energy.

Nature offers certain natural sources of energy—the winds, waterfalls, etc. The other great source of energy is combustion. With the steam engine, fuel is burned under the boiler, and the heat transforms water into a

vapor under pressure. In internal-combustion motors, the combustion of a liquid or gas takes place explosively within the cylinder.

In both forms of combustion, chemical energy is transformed into thermal energy through atomic rearrangement and combination between the combustible elements of the fuel used and the oxygen of the air. The function of the engine is to transform the thermal energy into kinetic energy of moving masses. At the present time, there is no known way to avoid the wasteful transformations of energy involved in obtaining power from the combustion of fuels.

Engineers believe that practical methods will be developed before long for utilizing the direct *heat rays of the sun*, the energy of the *tides* and *waves of the ocean*, the enormous stores of *subterranean heat*, and possibly to obtain *electric energy direct from coal*.

Some physicists even believe that we are just skirting the fringe of vast stores of undiscovered energy. Whether it will ever be possible to release, direct, *atomic energy* in appreciable quantities, and at the same time be able to control it, or whether it will be possible to utilize the *energy of sunlight* by means of some photochemical or electrochemical process, transforming the energy of sunlight into electric energy, or even to control *gravitation*, are problems the answer to which must be sought, at present, from the romancers.

**Recent Applications of Standardization.**

Reverting to the evolution of standardization, as mentioned above, before the time of the mechanical revolution, power was produced by winds, falling or running water, or by human beings, horses, oxen, and the like. In early civilization, a very large proportion of mankind was employed in mechanical drudgery. The advent of mechanical power has changed all of this.

It was preliminary to big capitalism and large-scale organization of industry.

The mechanical revolution was the result of the development of organized and applied science. The industrial or economic revolution was the social and financial change in human conditions and affairs caused by the mechanical revolution. No definite date can be given for the beginning of the industrial revolution, and it is still in progress. Prior to this time, the worker had the skill; now the skill is in the machines. The effects of this transfer of skill were very great. Capital was now required to build machines and to provide power to operate them.

**Advances in the Industrial Arts.**

There are four major branches of industry—*agriculture*, *mining*, *manufacture*, and *railway transportation*. In this discussion of standards and standardization, manufacturing industry will receive the principal consideration. The other industries will be considered only incidentally.

In recent years, attention has been concentrated upon the material and mechanical sides of production and distribution in industry. Science has revealed the secrets of materials and the modern manufacturer can determine the most suitable materials and the most economical methods of fabrication to obtain the desired results.

One of the most modern aids to industry is *standardization*, which is now recognized as being of the greatest importance to both producer and consumer. It is sometimes said that the benefits of standardization are mainly to the producer. This is not the case; they are quite as important to the purchaser and user. In industrial standardization, it is the *consumer* who ultimately is benefitted most, but the immediate benefits

are largely to the *producer*, for it at once simplifies his work and enables him to produce what is required by the consumer more cheaply and expeditiously. With lower production costs comes more extended use of the standard article, for it is a law of economics that when costs increase, substitutes are used.

**Advance of Standardization in Industry.**

The next stage saw the United States rise from a relatively insignificant position to that of one of the great industrial and manufacturing nations of the world, both in quantity and diversity of products. As production increased, economies in the purchase of materials, indeed the control of sources of supply of materials, became possible, with integration of the various steps in the production of raw materials and manufacture of more and more refined products. Mechanical standardization spread from one process to another in the same industry, and from one industry to another, and gradually it was learned that machines adjusted to standardized work helped one another because of the uniformity of the product. So progress went on cumulatively. Each step forward made the next simpler, and by slow steps were evolved the fundamental notions of those *semi-automatic* and *automatic machines* of the present day, each of which performs a great many operations one after another on the material fed into it. Thus the gaps which had to be filled in by handwork constantly became fewer and shorter. Many types of automatic machines are now made which receive their raw material in the form of sheets, bars, rods, wire, etc., and deliver their product completely finished, even when complicated operations are required. A number of these machines can be taken care of by one operative, his duties being merely to see that new stock is always ready to go into

the feeding device, and to adjust or replace the cutting tools as they wear.

As manufacturing grew and industries became larger, there was developed the *American* type of manufacturing standardized, interchangeable parts.

### Importance of Transportation and Communication Facilities.

Modern industry and commerce demand *speed*, not only in production, but in the exchange of products and in the interchange of ideas.

The service rendered industry and commerce by improved methods of transportation and communication—roads, canals, steamships, railways, motor-propelled vehicles, airplanes, dirigibles, telegraphy, telephony, radio (audition), and now telepictography, radiotelegraphy and television—can hardly be expressed numerically.

In transportation, the railways, in particular, have enabled the output of commodities to be greatly increased, and the cost to be reduced very much, and as a result commodities that in earlier generations were regarded as luxuries are now considered necessities. The increased output and the reduced costs are attributable, in considerable measure, to economical means of transportation. Obviously, production cannot be carried on upon a large scale, thus securing the advantages that result from the division and specialization of labor and the use of machinery, unless the necessary raw material can be cheaply delivered at the plant and the finished products cheaply distributed to the consumers. Unless the raw materials lie close to the consuming markets, which is usually not the case, large-scale producers must either obtain their raw materials from a distance, or transport their finished products to distant markets, and perhaps both. The railways, by providing improved

means of transportation, have made this possible to an extent not dreamed of a hundred years ago. The increased output and the reduced costs are also attributable in large measure to the concentration of production at those points where conditions are most propitious.

With the growth of large-scale production and the localization of industry there has developed an ever-increasing dependence of the entire population upon *railway transportation.* Previous to the coming of the railway, each section of the country lived largely unto itself. There was relatively little intercommunication, and the exchange of products was limited to a degree that is difficult for modern generations to realize, because transportation was costly, slow, and hazardous. The railway, once it had passed beyond the experimental stage, introduced a new order by bringing the people into contact with one another and with new conditions which broadened their outlook, and diminished sectional prejudice and vanity. The railway also made it possible for goods to be carried in enormous quantities at low rates, and thus destroyed *economic self-sufficiency.*

The railway system of the world is man's most colossal monument to applied science.

It is because of standardization of industry that Western civilization has been able to forge ahead and Eastern civilization remains pretty much where it was one or two centuries ago. While we invite and secure the labor-saving devices which make life more enjoyable, through standardized methods of manufacture, the Oriental has denied himself these things, but has standardized his personal life. The Chinaman's clothes, thatched hut, wooden plow, and rice paddy are surely as standardized as anything found in American civilization. These things have been standardized there for centuries, and yet China has little desire to adopt modern machinery and methods. If the Chinaman had

more *standarized agricultural machinery, tractors, locomotives, and automobiles*, his life would become much less standardized, and he would not be bound by the unchanging customs of the past.

No one can doubt that the standardization of materials, machines, processes, and products of manufacture has been one of the prime aids of *American progress* in the industrial arts. When a standard gauge of track, standard couplers, air brakes, etc. were adopted for all railways, the unification of all the lines on the continent into a single system of transportation, by the interchange of cars, was made practically possible. Think what it would mean if each individual railway had its own gauge of track, so that no cars or locomotives but its own could run upon its rails! Think what it would mean if each make of automobile required its own peculiar tires and spark plugs! The efficiency of these great inventions would be so minimized as to be all but destroyed. In standardization, the same principle has been applied with equal advantage to a thousand other things, great and small.

The importance of standardization may be realized when it is remembered that modern civilization is industrial, and that the wonder of industry is mass production, which depends upon the standardization of processes, materials, and finished products and their components.

The engineer was on the firing line in the last industrial revolution. It is now evident that the chemist and metallurgist will be among the leaders in the next industrial revolution. The future of industry, as organized today, depends largely on materials.

For example, the introduction of manganese, chromium, and tungsten into steel has made *modern machinery* possible. Nickel, vanadium, and molybdenum have given steel the necessary high elastic limit and

great toughness to withstand the vibration of automotive and similar machinery. *Monel* metal, a natural alloy of copper and nickel, has given us a metal which will withstand corrosion. Stainless steel, which has come into quite general use for cutlery and other kinds of instruments, depends upon chromium for this valuable property.

The demands of the aeroplane industry for a strong light metal has been met by *magnalium*, an alloy of magnesium and aluminum, and *duralumin*, an alloy of copper and aluminum, but these light alloys are relatively expensive. Many electrical appliances require *resistors*, which are made of alloys of manganese and nickel and of chromium and nickel.

One of the urgent needs of industry, particularly in the various branches of transportation, is a *cheap* alloy of aluminum, magnesium, or other light metal, resistant to corrosion, light and strong, to replace steel for special uses.

Although modern methods of transportation are economical and efficient, still when it is considered how much *excess weight* per passenger, or per ton of freight, is moved in transportation, one is led to believe that this subject offers a possible field for further economy.

An ocean-going steamship, such as the *Leviathan*, moves 25,000 *pounds for each person* carried; on the *Twentieth Century Limited*, nearly 10,000 *pounds* are carried per person. An ordinary trolley car carries *two-thirds of a ton* dead weight per person, and a *five-passenger automobile* weighing 3,500 pounds carries 700 *pounds* dead weight per person. A *dirigible* carries about 1,000 *pounds* excess weight per person. A *commercial airplane* weighing 3,500 pounds and carrying, say, eight persons, has a dead weight of 438 *pounds* per person.

The cost of moving unnecessary *dead weight* represents a *direct waste*. The use of lighter metal construction

partially to avoid this loss is sure to come, and when the demand is sufficiently insistent, the chemist and the metallurgist will provide the method for making the alloy.

In no direction has man progressed so much in the last 2,000 years of civilization as in his commercial and industrial endeavors. Architecture, literature, art, and law, on the other hand, have made relatively less advancement.

In our modern economic life, however, with its production of goods for practical use, and their transportation, distribution, and exchange, the transformation is indeed a fundamental one. It would seem that we could nowhere measure the progress of civilization more directly than in these marvelous changes in *industry, trade, transportation, and commerce.*

**Standardization a Useful Servant, but a Bad Master.**

Standards should not be allowed to become so crystallized and set that their revision becomes a difficult and time-consuming process. *Standardization is a useful servant but a bad master.* If improperly used in a rigid, uncompromising way, standardization may obstruct progress; if properly used, standardization will be found to be a valuable aid to industrial advancement. Whether standardization becomes a hindrance or an aid, will largely depend upon the degree of flexibility of standards that is maintained, which involves a working arrangement so set up as to facilitate revision, and the full utilization of this arrangement by making revisions whenever this can advantageously be done.

**Modern Period in Industry.**

In the latter part of the nineteenth century, the era of simple *consolidations* in industry began. This was brought about by destructive competition, by the profit-

ableness of promoting these combinations, and for purely economic reasons.

As industries developed, they embraced much wider territories. Problems of exchange arose, finance became much more complicated, and the business cycle began to be discussed. Traffic management, advertising, and market analysis were developed. Purchasing was put on a more business-like basis, and economic and financial services were considered indispensable. Great credit organizations and banking institutions arose, and *industrial engineers* or *business doctors* appeared.

The industrial engineer or "business doctor" is equipped to analyze a business, to collect the facts, to arrange them in the order of their relative importance, and to apply the *scientific method* to what is needed. The application of this method to any problem, insures a decision based upon facts instead of upon opinion, and possession of the facts makes decision comparatively easy and certain.

**Recent Developments in Business.**

Yesterday's era was that of the rise of the modern factory system of manufacture, of the growth of machine production under standardized conditions of operation, and of simple industrial consolidations, both of manufacture and transportation.

Today's era is that of superconsolidations in industry and transportation, the most highly developed form of industrial evolution, symbolic of a changing economic order. The simple consolidation in industry is *organized horizontally*, so to speak, on one plane of production—a chain of shoe factories, for example. The superconsolidation may be organized downward in the progress of manufacture toward the raw material, and upward toward the sale of the finished product to the ultimate consumer. It is, in fact, often referred to as the *vertical combination*.

But its structure is often much more complex than these geometric phrases indicate. Some of the largest superconsolidations are highly organized *horizontally* on one or more planes at once; they may also be organized vertically in entirely separate industrial fields. This economic change has been an evolution from the small independent factory, performing but one of the functions of production, toward the superconsolidation, a complete and self-sufficient industrial organization. The Ford Motor Company is an illustration. The process is, in fact, sometimes called *industrial integration*, a good phrase which imparts the evolutionary meaning of the whole development.

We have the greatest industrial organizations in the world, engineering skill to rank with any, great versatility in applying machinery to the needs of man, enormous stores of raw materials, and magnificent facilities for transportation.

Pooled resources of capital, brains, machinery, and power make possible an accelerated improvement in the manufacturing process. Undreamed-of standardization and the resulting economy become possible. Nuts always fit bolts and parts fit accurately for assembly or replacement. Even more impressive are the wastes which are eliminated from the processes of manufacture. The entire business of production is geared as one interconnecting machine to the demand for the finished product. Not only is there coordination about the superconsolidation of industry, but there is balance and stability. The entire structure of our industrial and business life is entering a new stage of development.

The superconsolidations of industry are based upon certain impelling economic reasons, and if wisely done, attain the following results:

1. Insure lower cost of production through standardization and mass production.

2. Make mass purchasing possible with resulting reduced cost per unit.

3. Make maintenance of standard quality possible.

4. Reduce capital charges and depreciation on stores of standardized raw material and finished product.

5. Provide for pooling of expert knowledge, methods, and resources.

6. Reduce transportation charges.

7. Facilitate financing.

The formation of superconsolidations of industrial groups, with the inevitably resulting economies of highly standardized and coordinated operation, is now proceeding at a rapid rate in this economic drama.

Intensive *mass production, mass purchasing, mass selling, and mass credit* are the quadrangle on which modern industry and business are based.

Scientific management of these gigantic groups of industry, both manufacturing and transportation, with highly standardized operation, budgetary control, and coordinated effort, is the latest development of business.

## CHAPTER II

## STANDARDS

The governments of all civilized countries have established *standard money* for use in expressing value, and as a medium of exchange in the transfer of commodities, and *standard weights and measures* for determining their quantity. In proportion as these standards are fixed and enforced by law, trade is facilitated and made more equitable and economical. If it were possible to go further and fix and enforce *standards of quality* of commodities, still greater economies could be effected.

Standards of weight, measure, and money are essential for the free *interchange* of commodities in trade and commerce, by which progress in civilization is measured, so that standards are the basis of civilization.

The standard money in the United States, as in most other countries today, is gold coin.

The characteristics, usage, and application of standards must be clearly understood before they can properly and effectively be adopted and put into operation in science, industry, or trade; that is, before standardization can be effected.

Accurately established weights, measures, and other standards of quantity and quality are the tools of the scientist, engineer, and technologist, and they guide and control each step of every process of industry involving materials, machines, methods, and products. The establishment of such standards involves the highest scientific knowledge, skill, and precision of determination, definition, and measurement, and they approach per-

fection steadily through persistent research in laboratory, shop, and field.

The desirability of providing adequate *standards* is recognized in almost every line of industry. There are in each industry, however, the practical questions: "What shall the standards be?" "How shall they be determined?" "How can their acceptance best be accomplished?"

A standard may be concisely defined as a criterion, measure, or example, of procedure, process, dimension, extent, quantity, quality, or time, which is established by authority, custom, or general consent, as a definite basis of reference or comparison.

The *National Bureau of Standards* is recognized as the highest authority in this country, and one of the highest in the world, on the development and definition of basic scientific standards. The Bureau classifies and defines standards and their purposes, in detail, under the following headings:

1. Standards of Measurements.
2. Standard Constants.
3. Standards of Quality.
4. Standards of Performance.
5. Standards of Practice.

**1. Standards of Measurement.**

Reference and working standards for measurements of all kinds, including fundamental and derived standards of measurement for expressing the quantitative aspects of space, time, matter, energy, and motion, and of their interrelations.

By definition, specification, or material standard, covering, for example, length, area, and volume; mass, weight, density, and pressure; heat, light, electricity, and radio-activity, including for each the quantity, flux, intensity, density, etc.

**Purpose:**

To aid accuracy in industry through uniform and correct measures;

To assist commerce in size standardization of containers and products;

To promote justice in daily trade through systematic inspection and regulation;

To facilitate precision in science and technologic research through calibration of units, measures, and instruments involved.

The science of physics begins with measurements, and at the very outset of our discussion of standards it may be well to recall an old saying of Plato: "If arithmetic, mensuration, and weighing be taken away from any art, that which remains will not be much."

The exact measurement of all the quantities involved in any phenomenon is a very important part of its study. It is largely owing to the recognition of this fact that such great advances have been made in the science of physics during the last 200 years. Perhaps the greatest achievement of modern science is its ever-increasing capability to measure.

The quantitative measure of anything is expressed by two factors—one, a certain definite amount of the kind of physical quantity measured, called the unit, the other, the number of times this unit is taken. A distance is stated as so many units of length, as so many meters, yards, etc. Similarly, quantity of matter is referred to as so many grams, pounds, etc.; time, as so many seconds, minutes, or hours.

The different kinds of quantities measured by physicists and engineers fall fairly definitely into two classes. In one class the magnitudes may be called *extensive*, in the other *intensive*. To decide to which class a quantity belongs, it is often helpful to note the effect of the addition of two equal quantities of the kind

in question. If twice the quantity results, then the quantity has extensive (additive) magnitude. For instance, two pieces of platinum, each weighing 5 grams, added together, weigh 10 grams; on the other hand, the addition of one piece of platinum at 100°C., to another at 100°C., does not result in a system at 200°C. Volume and energy may be taken as typical of extensive; density and temperature, of intensive magnitudes.

The measurement of quantities having extensive magnitude is a comparatively direct process. Those having intensive magnitude must be correlated with phenomena which may be measured extensively. For example, in the case of temperature, a typical quantity with intensive magnitude, various methods of measurements have been devised, such as the correlation of magnitudes of temperature with the varying lengths of a thread of mercury.

It is desirable that the fewest possible fundamental unit quantities be chosen. The choice should be determined by simplicity; first, *psychologically*, in that they should be easy to grasp mentally; and second, *physically*, in permitting as straightforward and simple a definition as possible of the complex relationships involved.

**Kinds of Units.**

It has been found possible to express all measurable physical quantities in terms of five such units: first, geometrical consideration, length, area, etc. lead to the need of a *length unit;* second, mechanics, treating of masses instead of immaterial points, introduces matter with the need of a fundamental *unit of mass;* third, kinematical considerations, velocity, acceleration, etc. introduce *time;* fourth, *thermal*, and fifth, *electrical* considerations require two more such quantities.

Each of the units employed might be arbitrarily chosen without reference to any other; the inch might

be taken as the unit of length, the square foot as the unit of surface, and the quart as the unit of volume; but such a practice would lead to endless complications, especially when several different units are used in the same calculation, for it would be necessary in such a case to keep constantly in mind the number of square inches in a square foot, the number of cubic inches in a quart, etc. It is far simpler after choosing the inch as the unit of length to take the square inch as the unit of surface and the cubic inch as that of volume. The same principle applies in the case of all other units; none should be chosen arbitrarily which can be directly derived from those which have previously been selected.

A system such as this, in which there are a few arbitrarily chosen fundamental units, between which no known connection exists and from which all other units are derived without introducing any new arbitrary factors, is known as an *absolute system of units.*

All the phenomena of nature are made manifest to us in *time* and *space,* through the agency of *matter.* It is natural then, that the fundamental units adopted as the basis of the system of measurement used in science and industry should be the units of *length, mass,* and *time.*

Physicists usually employ what is called the *centimeter-gram-second* (c.g.s.) system of absolute units in which the centimeter, gram, and second are taken as the units of length, mass, and time, respectively. This system has the advantage of being in use by physicists all over the world, and, therefore, results expressed in its units are universally intelligible. These are also convenient units, for lengths, masses, and times may be compared with great ease and precision, and all units that relate only to mass, motion, and force, or that depend on these by definition, may be derived directly from them.

An absolute system, however, might be based on any three units of length, mass, and time whatever. For

example, a *foot-pound-second* system is used extensively in English-speaking countries.

**Units and Standards.**

*Units* of measurement and *standards* for measurement are often confused in use, particularly in the case of length and capacity.

A *unit of measurement* is fixed by definition, and is independent of temperature, pressure, or other physical condition. For example, the unit of length is a fixed distance, and the unit capacity is a specified volume.

A *standard for measurement* is the physical embodiment of the corresponding defined unit. In general, a standard is not independent of temperature, or other physical conditions, and it is a true representation of the corresponding unit only under definitely specified conditions. For example, a meter standard or a yard standard may be made of any specified material, and it is a true representation of the unit only at a certain specified temperature and under other specified conditions. Similarly, a capacity standard contains a given number of units of volume at some definite temperature.

Such confusion as has occurred in the use of the terms *units* and *standards* has come about largely through the use of the same name to designate both the unit and the standard. Thus the term *meter* is used to designate both the unit (that is, the defined distance) and the physical embodiment of the unit (that is, the standard); similarly, the term *yard* is used to designate both the defined unit and the physical embodiment of the unit. This dual use of the same terms for other units and their corresponding standards makes it necessary in any technical discussion of measurements to indicate clearly the sense in which the terms are used.

A measurement is a *comparison* of the thing being measured with the standard, and if high precision is

desired, it is necessary to specify accurately and comply with the conditions under which the measurement (comparison) is to be made.

The demands of modern science and industry require, for certain purposes, an extremely high degree of accuracy in these fundamental comparisons. No measurement, however, is ever absolutely correct. Some degree of experimental error is always unavoidably present.

The unit must be of the same nature as the quantity which is to be measured, since only like things can be compared. There must, therefore, be as many different kinds of units as there are kinds of quantities to be measured.

In the establishment of metric standards, the earth furnished three units. The unit of length, the meter, was derived from and once defined as one ten-millionth of the earth's quadrant; the unit of time, the second, is based upon one rotation of the earth on its axis; standard gravity is the acceleration of a falling body produced by the earth's attraction. Water furnished four units of measurement; the unit of volume, the liter, is the volume of a kilogram of water; unit mass, the kilogram, was originally defined as the mass of a cubic decimeter of water; the unit of temperature, the degree (Centigrade) is one-hundredth of the interval between the ice and steam points of water; the unit of heat, the calorie, is the quantity of thermal energy which will raise the temperature of 1 gram of water 1°C. Water also is unity in expressing density in grams per cubic centimeter. These values are basic standards. So far as they determine units of measure, a knowledge of their measured value is as essential as a yardstick in measuring length.

As the result of innumerable experiments, physicists have concluded that heat, light, sound, and all electrical and magnetic actions are manifestations of *energy*, and require energy to be expended in causing them, exactly

in proportion as they are capable of doing mechanical work or developing heat.

Every experiment or process in which energy or matter are involved, and in which quantity has to be determined, includes measurement in some manner, and *measurements*, in turn, *depend upon standards*.

**Units and Standards of Length.**

The unit of length in the c.g.s. system of absolute measurements is the *centimeter*, or one-hundredth part of a meter. The meter was intended to be exactly one-ten-millionth part of the distance from the equator to the pole measured along a meridian on the earth, and was originally adopted with the view to its becoming a universal standard of length. It is now known that the earth's quadrant on the meridian passing through Paris is about 10,002,288 meters in length, but as distances can be more easily and accurately compared with the length of a material standard than with the length of the earth's quadrant, the international meter, as represented by a certain bar of platinum-iridium (90 per cent platinum and 10 per cent iridium), when at the temperature of melting ice, has been adopted as the international primary standard of length. This *International Prototype Meter* is kept at Paris, at the International Bureau of Weights and Measures.

The standard meter bar has a total length of 102 centimeters, and has a cross-section of a modified X form, designed by M. Tresca. This profile was chosen because of its low-temperature lag, and because maximum rigidity is attained with a minimum amount of metal, which is desirable for economic reasons, as platinum-iridium alloy is very expensive. Furthermore, in the line standard bar, the median plane, or plane of neutral fibres, lies exactly at the cross-sectional center of the bar. The lines are ruled at each end on well-polished

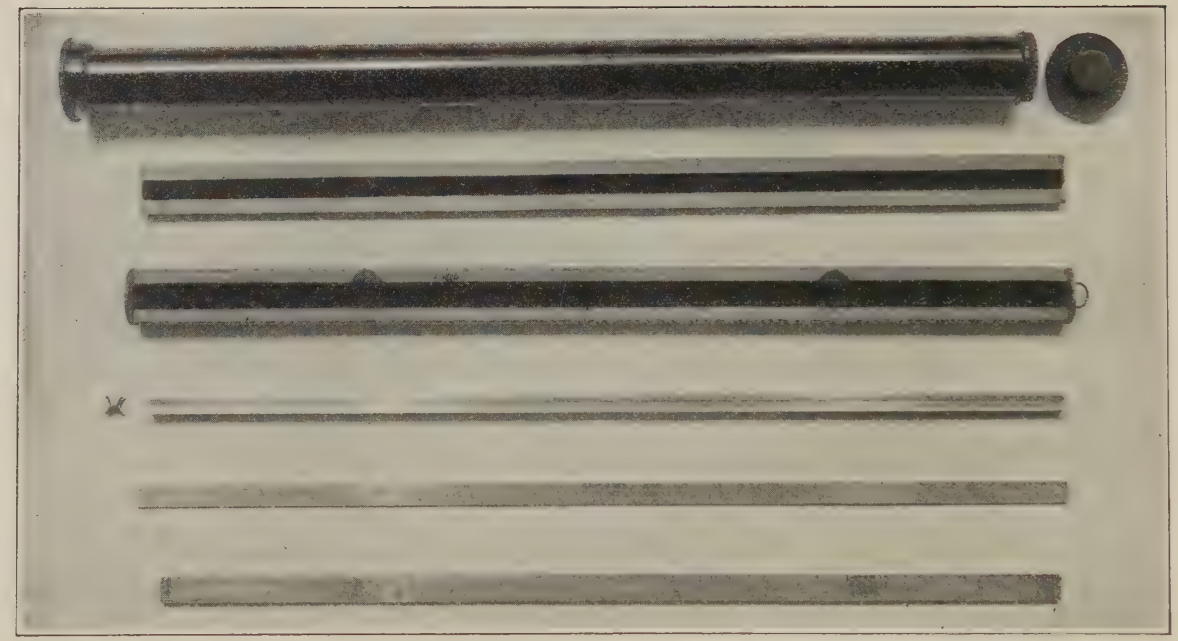
areas in the neutral plane. The axis of each bar is defined by two parallel lines about 0.2 millimeter apart. At each end the axis is crossed perpendicularly by a group of three lines about 0.5 millimeter apart. The length represented by the bar (1 meter) is defined as the length of the axis intercepted between the central lines of the group of lines at either end of the bar. All of the lines are very fine and have sharp, smooth edges. Care was taken to make both the rulings and the polish of the surfaces so uniform that both ends appear alike when viewed under a high-power microscope.

*National Prototype Meter No. 27* (Fig. 1) is the primary standard of length in the United States. It is one of thirty such prototypes, made and tested at the same time by a special committee of the International Bureau of Weights and Measures at Paris. One of the lot was selected to be the international primary standard of length and is known as the International Prototype Meter. The remaining meters were distributed by lot to the various governments in the international organization.

Prototype Meter No. 27 was adopted in 1893 as the primary standard of length in the United States because it was superior to either of the two previous standards in shape, sharpness of lines, and permanence of length. Sealed in its metal case, meter No. 27 is preserved in the fireproof standards vault at the National Bureau of Standards at Washington, D. C.

Meter No. 21 is occasionally used to verify the secondary or working standards of the Bureau, and in special cases, where the highest accuracy is required, other meters are compared with it.

The Bureau also possesses two other platinum-iridium standard meters. These are known as No. 4 and No. 12, respectively. These four platinum-iridium meter standards all have the same cross-sectional form and



*(Photograph furnished by courtesy of the National Bureau of Standards)*

FIG. 1.—Standards of length.

The upper three views show different parts of the case in which National Prototype Meter No. 27 is stored. The fourth view from the top is National Prototype Meter Bar No. 27, which is the fundamental length standard of the United States. The view to the left of the meter bar shows the crosssection of the bar. Its length is certified to in terms of the International Prototype Meter when at the temperature of melting ice.

The bar next to the bottom is an invar meter bar which serves as a secondary standard at the National Bureau of Standards.

The bar at the bottom is a bronze copy of the British Imperial Yard.

These standards are kept in the standards vault at the National Bureau of Standards, at Washington, D. C.

have been certified in terms of the International Prototype Meter by the International Bureau of Weights and Measures. The No. 4 meter is divided into millimeters for its entire length, and in addition is ruled with a special line to define the yard. The three secondary standard meter bars of platinum-iridium, Nos. 4, 12, and 21, are sometimes used as working standards for work of very high precision. These three meter bars are practically on a par with meter No. 27, except in the matter of formal recognition.

In 1921, National Prototype Meter No. 27 was returned to the International Bureau of Weights and Measures at Paris for recomparison with the International Prototype Meter. It was found that our national standard of length has remained constant, within the errors of the most precise measurements, since its original comparison in 1889. In 1923, it was returned to the National Bureau of Standards.

These standard meters are the only units of metric extension by which all other metric measures of extension —whether linear, superficial, or solid—are ascertained.

While the usual units, multiples, and submultiples of the meter down to the millimeter, or the hundredth part of the centimeter, answer many purposes of the scientist and engineer, yet in some work they do not carry them far enough, and accordingly they have added the *micron*, which is one-thousandth part of the millimeter. The micron is used in refined work in metrology. The *millimicron*, the *Ångström*, and *milliangström*, are further subdivisions of the millimeter which are used for expressing wave lengths in radiation measurements. The relationship of these new metric units is as follows:

| | | | |
|---|---|---|---|
| Micron | $\mu$ | = 0.001 | millimeter = $10^{-3}$ mm. |
| Millimicron | m$\mu$ | = 0.000,001 | millimeter = $10^{-6}$ mm. |
| Ångström | Å. | = 0.000,000,1 | millimeter = $10^{-7}$ mm. |
| Milliangström | mÅ. | = 0.000,000,000,1 | millimeter = $10^{-10}$ mm. |

These subdivisions of the millimeter are also used in expressing linear dimensions of extremely minute particles of materials, cells, bacteria, and the smallest vegetable and animal organisms. They afford convenient units for microscopic and spectroscopic work.

The relation between National Prototype Meters No. 27 and No. 21, respectively, and the International Prototype Meter, is given by the following equations:

$$\text{Meter No. 27} = 1 \text{ meter} - 1.6\mu + 8.657\mu t + 0.00100\mu t^2;$$
$$\text{Meter No. 21} = 1 \text{ meter} + 2.5\mu + 8.665\mu t + 0.00100\mu t^2;$$

in which equations $\mu$ denotes a micron or thousandth part of a millimeter, and $t$ represents the number of degrees of the Centigrade scale of the hydrogen thermometer. The probable error of a comparison of the meter prototypes does not exceed 0.2 micron.

Other working standards at the Bureau of Standards are of an H-shaped cross-section and are made of 36 per cent nickel-steel alloy (invar). Half-meter bars, decimeter bars, and various special graduated bars and scales are also used as standards for length measurements where line standards are required. For contact length measurements, the working standards are precision gauge blocks, micrometer screws, etc.

Similarly, the British standard of length, from which the foot and inch are determined, is the Imperial Standard Yard, which is the distance between the centers of the transverse lines on the two gold plugs in a certain bronze bar deposited in the Standards Department of the Board of Trade, London, when measured at the temperature of 62°F. This standard yard represents about the average length of the early yard measures that were in use, which were probably adopted as being half the distance which a man can stretch with his arms. The Bureau of Standards has a bronze copy of the British Imperial Yard. In the United States, the official

relation between the yard and the meter is 1 yard/1 meter = 3,600,/3,937.

Light waves are now measured with high precision. The science of optics calls for light sources of standard wave length. Unexpected as it may seem, the precise measurement of wave lengths of light led to revolutionary achievements in the construction of length standards. Experts have measured tens of thousands of light waves of the rays characteristic of the chemical elements, waves of the order of one-fifty-thousandth inch. The precision is notable, the error being less than 0.000,000,000,004 inch.

If the International Prototype Meter disappeared and all the other standards of length were lost or destroyed, they could be reproduced, since the meter is now known in terms of a fundamental constant of nature—the constant called the wave length of a specified kind of light.

In 1927, the International Committee on Weights and Measures provisionally adopted a *wave-length standard of length* for this most fundamental measurement. The red ray given off by atoms of cadmium vapor, when these atoms are electrically excited in a vacuum tube, was the wave length selected.

Physicists have determined, after making this comparison with all possible precautions against error, that the International Prototype Meter equals 1,553,164.13 wave lengths of the red ray of the cadmium spectrum, in dry air at 15°C. and 760 millimeters of mercury. This value is probably correct to 1 part in 10,000,000; that is, the meter may be defined, in terms of light waves, with an accuracy of 1 *part in* 10,000,000. These measurements are among the most precise that have ever been made.

For the routine work of testing at the National Bureau of Standards, use is made of the secondary or working standards where values are carefully determined by

comparison with Prototype Meter No. 21 from time to time to detect any possible changes. The working standards include multiples and submultiples of the meter and of the yard.

For precision metal tapes and for some standards of length, Guillaume's alloy (invar) of 36.0 per cent nickel-steel is used, as it is a metal that can be highly polished, and is capable of receiving fine graduations. Its mean coefficient of linear expansion between 0° and 40°C. is of the order of one- to two-millionths for the ordinary invar. Steel tapes are usually compared with the steel bar bench standard 50 meters long with graduations ruled on inlaid platinum-iridium plugs.

A standard of length must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. In order to carry out such comparisons, working standards must be prepared which are subdivisions and multiples of the fundamental standard, and this process of subdividing and multiplying the standard involves difficulties as great as those met with in the preparation of the fundamental standard itself. At the present time, the accuracy of scientific length comparisons as made by the physicist, has been developed to an almost unbelievable degree.

**Units and Standards of Mass.**

The unit of mass in the c.g.s. system is the gram, or one-thousandth part of the standard kilogram, which is a cylinder of 90 per cent platinum and 10 per cent iridium alloy with diameter and height equal and with slightly rounded edges, and is known as the *International Prototype Kilogram K*. This international primary standard of mass is kept at Paris at the International Bureau of Weights and Measures.

The primary national standard of mass of the United States is *Prototype Kilogram No.* 20. It was constructed under the terms of the international treaty known as the Convention of the Meter, and was received by the President of the United States on Jan. 2, 1890, and accepted on behalf of the government; its mass is certified in terms of the International Prototype Kilogram.

This standard is one of 40 such prototypes made and tested at the same time. One of the lot was selected to be the international standard, and others were then distributed by lot to the various governments in the international organization. In addition to kilogram No. 20, the United States received also kilogram No. 4, which now constitutes the best of the secondary standards, being practically on a par with kilogram No. 20, except in the matter of formal recognition.

The relation between National Prototype Kilograms No. 20 and No. 4, respectively, and the International Prototype Kilogram *K*, is given by the following equations:

Kilogram No. 20 = 1 kilogram − 0.039 milligram;
Kilogram No. 4 = 1 kilogram − 0.075 milligram.

The probable error of a comparison of the kilogram prototypes does not exceed 0.005 milligram.

Prototype Kilograms No. 20 and No. 4 are now kept on polished plates of crystal quartz, each under two concentric bell jars (Fig. 2) in the standards vault of the National Bureau of Standards in Washington, D. C.

The material of which the international and national prototype metric standards of length and mass are made, platinum-iridium, was selected because it was believed to be, of all substances, the least affected by time or circumstance. Platinum-iridium alloy is exceedingly resistant to corrosive attack, and the constituent

*(Photograph furnished by courtesy of the National Bureau of Standards)*

FIG. 2.—United States Prototype Kilograms No. 20 (on the right) and No. 4 (on the left). Their mass is certified to in terms of International Prototype Kilogram *K*, the international standard of mass. The standards rest directly on polished plates of crystal quartz, under double bell jars, in the standards vault of the National Bureau of Standards, at Washington, D. C. They are handled by special lifting forceps faced with a soft material. From these standards are derived the values of all weights used in this country.

metals are not subject to atomic disintegration by radioactive processes, as far as is known.

Among the more important *secondary standards* of mass are a set from 500 grams to 1 milligram made of the same material as the national prototypes; four standards of 1 avoirdupois pound each, of heavily gold-plated Tobin bronze; together with one standard of 10 troy ounces and two of 1 troy pound, also of gold-plated bronze. These and certain other secondary standards are occasionally used for extremely accurate work, while still others derived from these are used as ordinary *working standards* for most of the work.

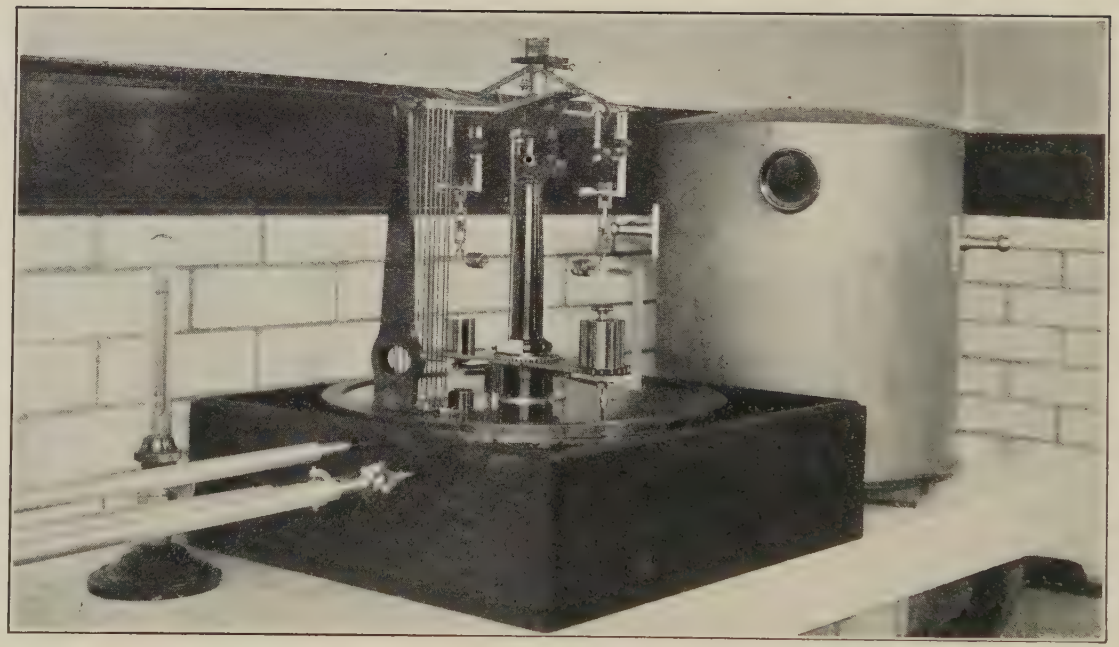
The working standards range from 0.05 milligram (about 0.000,000, 1 pound), used in testing small weights for laboratory work, up to test cars of 80,000 pounds, used in testing railroad track scales.

The following equivalents are used in defining the relations between metric, avoirdupois, troy, and apothecaries' units:

1 pound avoirdupois = 0.453,592,427,7 kilogram;
1 pound avoirdupois = 7,000 grains;
1 pound troy or 12 apothecaries' ounces = 5,760 grains.

The value of National Prototype Kilogram No. 20 is known in terms of the International Prototype Kilogram to an accuracy of about 1 *or* 2 *parts in* 100,000,000. Mass standards can now be compared with each other with a precision a little beyond this, but there are few such standards that will not change their values by more than 1 part in 100,000,000, even when not used.

The precision of mass determination is at present limited by minute uncertainties in calculating air density, which must be done to make correction for air buoyancy, and by uncertainty as to variations in the air and water vapor film that adheres to the surface of the weight (Fig. 3).



*(Photograph furnished by courtesy of the National Bureau of Standards)*

FIG. 3.—*Stückrath balance* for precision mass determination. This balance is used at the National Bureau of Standards for the most accurate weighing work. It has a capacity of 1 kilogram (2.2 pounds) and is sensitive to one-hundredth of a milligram, and, therefore, has a sensibility of one part in one hundred millions (1:100,000,000).

The metal case sets over the entire balance; the air can be pumped out and the weighing done in as perfect a vacuum as is desired. The weights are manipulated by mechanical means from an adjoining room, to avoid interference from the heat of the operator's body.

This balance has such a high degree of sensibility that it will detect the difference in weight (attraction of the earth) in a kilogram weight when it is raised or lowered 2 inches on the balance pan.

**Distinction between Mass and Weight.**

Mass standards frequently are called *weights*. Confusion often arises from the indiscriminate use of the term *weight* in two other senses; first, to denote the mass of a body, and, second, to refer to the force with which gravity acts upon such a body. The former is really an incorrect use of the word, due to failure to discriminate between the two ideas. Of course, it is readily understood that when we speak of a 2-ton block of iron, and a tension of 2 tons in a stretched rope, we refer in one case to a mass and in the other to a force.

It should be kept in mind that, whereas the *mass* of a body is a property inherent in the body itself, its *weight* is a measure of the mutual attraction between the body and the earth, varying on that account with altitude, latitude, and other circumstances. This variation of weight with locality, though amounting only to about one-half of 1 per cent over the entire surface of the earth, is perfectly definite, and can be detected by means of a sensitive spring balance.

Weight is measured in units of *force*. As it is not possible or desirable to base the unit of force on some concrete standard force, it is derived from the units of mass and acceleration. The c.g.s. unit of force, the *dyne*, is thus derived. It is common, however, to express weight in terms of the gravitational unit of force. This unit is the force of gravity that acts on a body per unit of mass (in vacuo) at any place where the acceleration is 980.665 cm./sec.$^2$ (= 32.1740 ft./sec.$^2$), in accordance with the definition of standard weight and standard gravity by the International Committee of Weights and Measures.

The standard kilogram was intended to represent the exact mass of a cubic decimeter of distilled water at its greatest density, or at the temperature 4°C. Since two

masses can be compared with a far greater degree of accuracy than that with which the volume of a cubic decimeter of water can be determined, the kilogram has been adopted as the real standard on which are based all metric weights, and all measures having reference to metric weight.

It has been found, however, that a cubic decimeter of water, when at the temperature of its maximum density, has a mass slightly less than 1 kilogram. While it would have been possible to decrease the kilogram slightly, thus making it equal to the mass of a cubic decimeter of water, this was not done, but, instead, a new definition of the unit of capacity, the liter, was adopted, namely, the volume occupied by a quantity of water having a mass of 1 kilogram when at the temperature of its maximum density. The liter, which is greater than the cubic decimeter, by about 27 parts in a million, is the unit ordinarily employed in measurements of density and volume of liquids. The one-thousandth part of the liter, the milliliter, is also very often employed.

In the United States, the official relation between the liter and the gallon, liquid measure, and the quart, dry measure, are as follows:

1 liter = 0.264,178 U. S. gallon, liquid measure;
1 liter = 0.908,102 U. S. quart, dry measure.

Definitions and equivalents of various units of length, area, volume, capacity, and mass, derived from the meter, kilogram, yard, and pound, are given in Bureau of Standards *Circular* 47.

In constructing a set of standard weights from a single standard, a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. Before these working standards, made up of subdivisions and multiples of the fundamental standard, can be prepared, questions

as to the methods of comparision arise, which again involve the solution of difficult scientific problems in connection with the balance for weighing, or the methods used. The complete range must be covered, which involves not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the weights found in practice.

These length and mass standards and equipment for measurement are absolutely essential in order to secure uniform measurements of length and weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, heat, temperature, light, or the various electrical or other standards of measurement. These standards, in one form or another, are involved in practically every scientific investigation, industrial process, engineering structure, or commercial transaction.

**Unit and Standard of Time.**

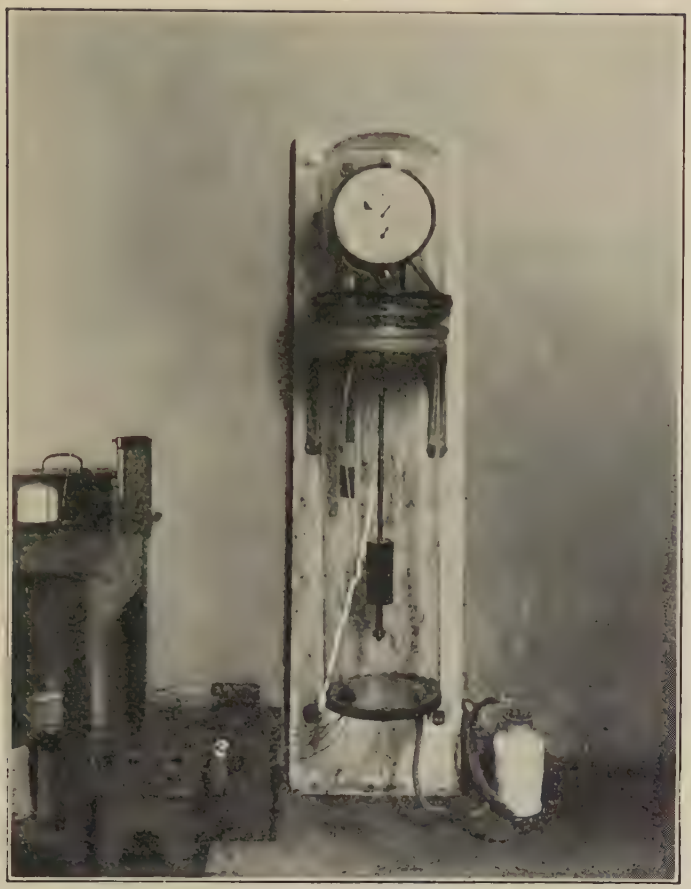
Intervals of time are always compared by the motions of bodies. Two intervals of time are defined as equal when a body, moving under exactly the same circumstances in both cases, moves as far in the one time as in the other. The heavenly bodies have, in their motions, always furnished measures of time. One of the simplest natural units of time is the period of rotation of the earth, which is the interval of time between two successive meridian passages of the same star. This is known as the *sidereal day*, and time reckoned in this way is called *sidereal time*. Early in the nineteenth century, Laplace and Poisson were believed to have proved that the length of the sidereal day had not changed by as much as the one-hundredth part of a second during the last 2,500 years, but later investigations show that they were mistaken and so far as can now be seen, tidal friction

must be steadily reducing the velocity with which the earth rotates on its axis. The change is too slow to become sensible during the lifetime of a human being. Theoretically, however, the unit of time is slowly increasing in magnitude.

J. Clerk Maxwell several years ago proposed the period of vibration of some determined kind of light as an ultimate unit of time; for example, the red cadmium ray, the wave length of which has been provisionally adopted (1927) as the ultimate unit of length. This would be permanent in magnitude.

The ordinary day is determined not by the rising and setting of the stars, but by the apparent motion of the sun. When the sun is on the meridian, it is said to be solar or apparent noon. The interval to time between two successive apparent noons is called the apparent or solar day. It is this time which is indicated by the sun dial. By means of clocks, which are machines constructed to run with great uniformity, one solar day may be compared with another, and it is thus found that they are not of equal length. The average length of the solar days in a year is known as the mean solar day. The ordinary *standard time* used in everyday life is mean solar time. The *unit of time* in the c.g.s. system is the *mean solar second* or 1/86,400 part of a mean solar day.

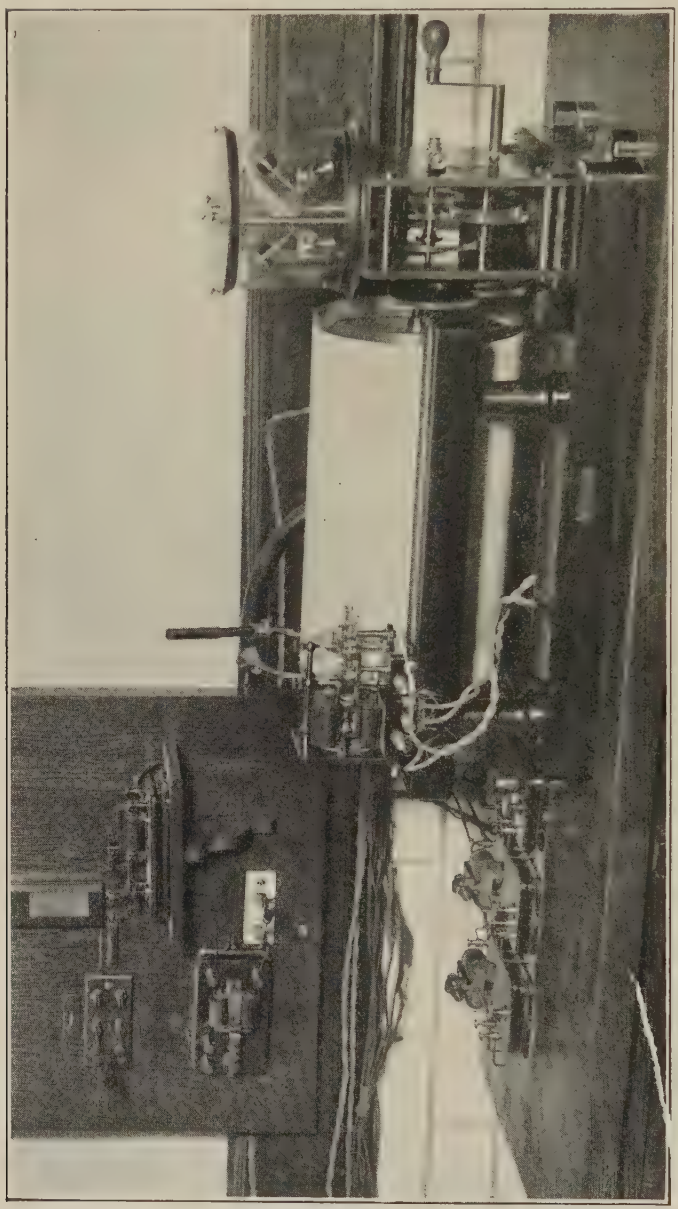
The standard of time measurement at the National Bureau of Standards is the high-precision Riefler clock (Fig. 4), which is capable of keeping correct time to within 0.02 second a day. This clock is provided with an invar pendulum which swings in a partial vacuum. Means are also provided for changing the pressure within the air-tight glass chamber which incloses the entire clock, thus regulating the rate of swing of the pendulum. The second signals from the clock are conducted electrically to the testing laboratory, where they are recorded automatically.



(*Photograph furnished by courtesy of the National Bureau of Standards*)

FIG. 4.—Riefler mean time clock used in the testing of watches and other timepieces. It is enclosed in an air-tight glass case, in a partial vacuum, and kept in a constant temperature room in the basement of the Administration building at National Bureau of Standards. The clock is provided with an invar pendulum, and is checked daily at noon with radio time signals, through the Arlington radio station, from the United States Naval Observatory, where the time is obtained by astronomical observations. The rate of this clock varies only a few hundredths of a second per day. An electrical winding mechanism winds it every 30 seconds, and an electric circuit-breaking device enables it to send second signals to the chronograph shown in Fig. 5, in the time laboratory, with which it is electrically connected.

Audible time signals are obtained from the free-swinging pendulum, with which there is no mechanical connection. A beam of light is cut by the pendulum at each swing; this changes the resistance of a photoelectric cell, and the current is amplified and transformed into an audible signal.



(*Poghotraph furnished by courtesy of the National Bureau of Standards*)

FIG. 5.—Electric drum chronograph on which time signals from the Riefler clock and radio time signals from the United States Naval Observatory, as broadcast by the Arlington radio station, are recorded automatically on a sheet, as notches in a continuous pen-traced line. The speed of the drum is so regulated that the pen travels 2 centimeters per second, and the time of the two signals may easily be compared to 0.01 second by means of a scale.

Precision time measurements in research may be made to within 0.001 second, and intervals of time to the order of a millionth of a second have been measured. The Bureau Riefler clock time is compared daily with noon signals from the Naval Observatory as received by radio through the Arlington radio station. These signals are recorded automatically on the sheet of a drum chronograph (Fig. 5), together with the signals from the Riefler clock, as notches in a continuous pen-traced line. The speed of the drum is so regulated that the pen travels 2 centimeters a second, and the time of the two signals may be easily compared to 0.01 second by means of a scale. Thus time is reduced to a traced line upon which notches represent definite time observations.

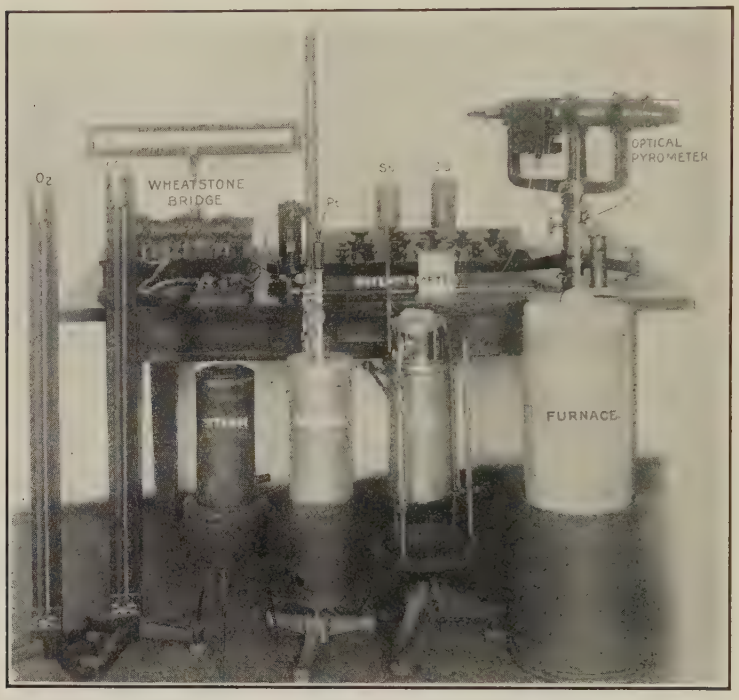
Nevertheless, clocks and chronometers are but adjuncts to our chief timepiece, which is the earth itself, and upon the assumed constancy of its rotation depends the preservation of our present unit of time.

**Units and Standards of Heat and Temperature.**

The standard scale of *temperature*, or intensity of heat, as adopted by the International Committee of Weights and Measures (1887) depends on the constant-volume hydrogen thermometer. The hydrogen is taken at an initial pressure at 0°C. of 1 meter of mercury, 0°C., sea level at latitude 45 degrees. The scale is defined by designating the temperature of melting ice as 0°; and of condensing steam at 100° under standard atmospheric pressure. This is known as the Centigrade scale. In engineering work, especially in English-speaking countries, the Fahrenheit scale is in common use. On this scale, the freezing point is marked 32°, and the boiling point 212°.

The apparatus for reproducing the standard temperature scale is shown in Fig. 6.

The platinum resistance thermometer *Pt*, used to reproduce the standard interval from 195 to 450°C., is calibrated at the boiling point of oxygen (−183°C.), the sublimation temperature of carbon dioxide (−78°.5C.), the melting point of ice (0°C.), the boiling point of water (100°C.), and the boiling point of sulphur




(*Photograph furnished by courtesy of the National Bureau of Standards*)

FIG. 6.—Apparatus for reproducing the standard temperature scale.

(444.°6C.), all under normal atmospheric pressure. The thermocouple *TC*, used to reproduce the standard scale from 400 to 1000°C., is calibrated at the freezing point of zinc (419.°4C. in furnace), antimony (630°C.), and copper (1083°C.). The standard scale above 1000° is reproduced by means of the optical pyrometer, which is standardized at the freezing points of pure metals (gold,

palladium, etc.), which are melted in the small crucibles shown. In the cut, the pure materials are indicated: Sb, antimony; Cu, copper; Pt, platinum; and $O_2$, oxygen.

The *quantity of heat* is ordinarily measured in thermal units, that is, in terms of the amount of thermal energy required to raise the temperature of a unit mass of water 1° of temperature at some stated temperature. This involves the unit of mass and some unit of temperature. If the metric unit of mass, the gram, and the Centigrade degree of temperature are taken, the thermal unit is the *calorie*, which is the amount of heat necessary to raise the temperature of 1 gram of water 1°C. Engineers in English-speaking countries commonly reckon the quantity of heat in *British thermal units*, which is the heat required to raise the temperature of 1 pound of water 1°F.

The most convenient and accurate means for standardizing laboratory bomb calorimeters used to measure the heat of combustion of fuels, foods, etc. is by the use of standard materials of accurately known heat of combustion. In addition to naphthalene, which, as certified by the National Bureau of Standards, has a heat of combustion of 9,622 (20°) calories per gram of material weighed in air against brass weights, there are furnished also sucrose, 3,949 calories, and benzoic acid, 6,329 calories per gram.

Standardization by means of these substances consists in burning an accurately weighed amount of the substance in the bomb calorimeter under exactly the same conditions as when the bomb is used for heat of combustion measurements. This determines the rise of temperature of the calorimeter for the known amount of heat supplied, and, since the temperature rise is proportional to the heat supplied, it constitutes a standardization of the calorimeter. If the rise of temperature employed in standardizing is nearly the same as that

observed in ordinary use of the calorimeter, the effects of minor errors are minimized.

Standard melting or freezing points are used to fix the standard temperature scale for the calibration of thermometers and pyrometers. In addition to the temperature of steam from boiling pure water at 760 millimeters, which is taken as 100°C., and the temperature of melting ice from pure water which is taken as 0°C., the following approximately pure metals are certified by the National Bureau of Standards:

Tin, 231.9°C.; lead, 327.3°C.; zinc, 419.4°C.; aluminum, 658.9°C.; and copper, 1083.0°C.

**Units and Standards of Electrical Resistance.**

The *International Ohm*, the unit of electrical resistance, is defined as the resistance offered to an unvarying electric current by a column of pure mercury at the temperature of melting ice, 106.300 centimeters long, of uniform cross-section and having a mass of 14.4521 grams. The ohm was the first electrical magnitude for which a definite standard was established.

*Secondary standards*, derived from the mercury standards and used to give values to working standards, are certain coils of manganin wire kept in the national laboratories. Their resistances are adjusted to correspond to the unit or its decimal multiples or submultiples. The values assigned to these coils are checked from time to time with the similar coils of the other countries. The value now in use is based on the comparison made at the National Bureau of Standards in 1910 and may be called the 1910 *ohm*. Later measurements on various mercury standards checked the value then used within 2 parts in 100,000. Thus, the basis of resistance measurement is maintained, not by the mercury standards of a single laboratory, but by all the mercury standards of the various national laboratories; it is, furthermore, the

same in all countries, except for very slight outstanding discrepancies due to the errors of measurement and variations of the standards with time.

In ordinary measurements, working standards of resistance are usually coils of manganin wire (approximately 84 per cent Cu, 12 per cent Mn, 4 per cent Ni). They are generally used in oil which carries away the heat developed by the current and facilitates regulation and measurement of the temperature. The best type is inclosed in a sealed case for protection against atmospheric humidity. Varying humidity often changes the resistance of open coils to several parts in 10,000 higher in summer than in winter, while sealed 1-ohm and 0.1-ohm coils may remain constant to about 1 part in 100,000.

**Unit of Electrical Current.**

The *International Ampere*, the unit of electric current, was the second electrical magnitude for which a definite standard was established and is defined by the weight of silver (0.001,118 gram) it deposits in 1 second by electrolysis of a solution of silver nitrate. This quantity is the electrochemical equivalent of silver. The application of electrolysis to plating, or the coating of one metal with a deposit of another metal, is a process exactly similar to this method of measuring the electric current.

From its nature, it is impossible to maintain a standard of electric current.

**Unit and Standard of Electrical Pressure.**

The Weston normal cell is the standard used to maintain the *international volt* and, in conjunction with resistance standards, to maintain the international ampere. The cell is a simple voltaic combination having its anode, or negative electrode, of cadmium amalgam, consisting of 10 per cent by weight of cadmium and 90 per cent mercury. The cathode, or positive electrode, is

pure mercury covered with a paste consisting of mercurous sulphate, cadmium-sulphate crystals, and colution. The electrolyte is cadmium sulphate solution in contact with an excess of cadmium sulphate crystals. The containing vessel is of glass, usually in the H form. Connection is made to the electrodes by platinum wires sealed into the glass. The cells are sealed, preferably hermetically, and in use are submerged in a constant-temperature oil bath.

The *International Volt* is the electromotive force which, when steadily applied to a conductor the resistance of which is 1 *international ohm*, will produce an electric current of 1 *international ampere*.

The numerical relation between these three electrical units is called Ohm's law, and may be expressed as follows:

$$\text{Intensity of current in } \textit{amperes} = \frac{\text{electromotive force in } \textit{volts}}{\text{resistance in } \textit{ohms}};$$

$$\text{or,} \qquad I = \frac{E}{R}, \text{ from which, } E = IR \text{ and } R = \frac{E}{I}.$$

Experiment has shown that Ohm's law is accurately realized in practice, and, therefore, it is obvious that only two of these units require independent definitions, the third being derived from the other two. The ohm has long been accepted as one of the two fundamental units. The ampere was selected as the second fundamental unit on account of the accuracy of the silver voltameter. These three fundamental electrical units, and others derived from them, are in daily use in research work in laboratories and in industry.

It may be useful to point out that the relation expressed in Ohm's law is a general principle which is found to hold true throughout the workings of nature, including human affairs, namely, that the *result* attained

is proportional to the ratio of the applied *force* to the *resistance*.

The *international watt* is the energy expended per second by an unvarying electric current of 1 international ampere under the pressure of 1 international volt.

Modern uses of electricity depend largely upon conductivity, which is an important factor in the choice of wire thickness for transmitting power with low wire loss from resistance. Published standard copper tables for the use of scientists, electrical engineers, and others are based on the international value, and are used in engineering practice involving the design or electric power-transmission lines and the conducting elements of electrical devices.

Electricity performs its modern miracles because of the measured control of voltage, conductivity, capacity, inductance, etc., for which units and standards, methods of measurement, and tests are available. To measure the flow and behavior of electricity calls for precise methods.

The international ohm and the international ampere, together with the centimeter, gram, and second, are used as the bases of definition of a great many other electric and magnetic units, as well as units for *motion, speed, force, energy, power,* etc.

No standard is maintained for power or energy.

It is well to remember that all physical measurements are more or less inaccurate, and that the degree of precision desired depends on the purpose of the measurement. Each case should be given the accuracy it deserves. For example, a clinical thermometer is needlessly exact if certified better than 0.1°, and an error of 1 inch in determining the distance between two mileposts is a much less serious matter than an error of one-thousandth of an inch in an important bearing dimension of an automobile.

A fundamental standard for a great industry deserves days or weeks of the best scientific study. Fifteen years were well spent in preparing the national fundamental standards of length and mass of the National Bureau of Standards.

**The Metric System in Science and Industry.**

The metric system of weights and measures possesses many advantages over our present system, but there are so many serious objections to changing the present standards that the introduction of the metric system is making but slow progress in *industrial work.*

Substantially all American *scientific research work* is now carried on in the metric system. A few activities of the United States Government—the National Bureau of Standards, the Coast and Geodetic Survey, the Bureau of Chemistry and Soils, a part of the U. S. Customs Service, and the Bureaus of Medicine and Surgery of the Army and Navy—use the system every day. There is at least one American industry that uses the metric system exclusively, *i.e.*, the manufacturers of lenses for eyeglasses and spectacles. Bills to consumers of electricity for electric light and power are made out in terms of the kilowatt-hour, a unit based upon the metric system. All radio wave lengths are measured and expressed in meters.

The Baldwin Locomotive Works has built locomotives to special order for the French Government in the metric system of units, without changing their machinery, and found no difficulty.

There is, however, no marked tendency in the industries to replace the present system by the metric system.

## CHAPTER III

## STANDARDS (*Continued*)

There are many fixed relations among physical quantities, among chemical quantities, and fixed relations between physical and chemical quantities, the values of which are extremely important in certain applications. These values are usually termed *standard constants*, and are used in every branch of scientific work or industry.

**2. Standard Constants.**

Natural standards, or the measured numerical data as to materials and energy, known as physical or standard constants; that is, the fixed points or qualities which underlie scientific research and industrial processes when scientifically organized.

Mechanical equivalent of heat, light, electricity, and gravitation; specific densities; viscosities; melting and boiling points; heat capacity; heats of combustion; velocity of propagation of light, conductivities of materials to heat, sound, and light; electrochemical and atomic weights; and many similar magnitudes determined experimentally with maximum precision and referred to fundamental standards of measure.

**Purpose:**

To serve as an exact basis for scientific study, experiment, computation, and design;

To furnish an efficient control for industrial processes in reproducible and uniformly high quality in output;

To secure uniformity of practice in graduating measuring instruments, or in compiling tables for standards of

quality and performance, and wherever such uniformity is desirable;

To aid laboratory research by reducing errors and uncertainty caused by use of data of doubtful accuracy.

The density (heaviness) of materials is a type of physical constant of practical utility. Density is of concern in many ways. It determines the rise of slag in a steel melt, the flight levels of airships, the flow of cream from milk in a centrifugal separator, the stratification of gases in the air, the effectiveness of storage batteries, and many other phenomena. It determines the floating and water line of a vessel; water differs in density at surface and at keel, and it varies with the season. A ship's water line rises and falls with changes in density of the water with the same cargo. Density is also the basis for the manufacture, sale, and use of petroleum oils.

The amount of heat required to transform 1 pound of water into steam under normal conditions, and the relation between *heat* and *mechanical energy* are two important physical constants; their values are used in practically every computation in connection with the designing of steam engines and boilers, the tests of their efficiencies, or the measurement of their output. The amount of heat required to melt 1 pound of ice is an important constant in the refrigerating industries.

The melting point of pure tin (231.9°C.) safeguards steam boilers by means of the well-known tin boiler plugs, which, when heated to that temperature, melt and warn the fireman that the water level is dangerously low. This is an illustration of how a physical constant, the melting point of tin, safeguards life and property.

Freezing points (melting points) are physical constants which fix the standard temperature scale. By

research, the purity needed to give definite standard freezing (or melting) points has been attained. These give fixed points on the temperature scale by which thermometers and pyrometers for scientific and industrial use may be verified by the user.

The application of *heat* and *power* depends upon measured control. Success in the heat and power industries depends upon the proper use of the correct degree of heat, or temperature. This calls for exact and uniform measurements by means of standardized instruments; pyrometers for the steel mill, thermometers for the bakery, the clinic, and chemical works. Accurate pyrometric measurements fix the correct temperature of a furnace for a successful melt and determines how refractory the fire-brick lining must be.

The production of *cold* has become a great industry, which has been effectively served by the determination of the standard constants or basic data of refrigerating materials—ammonia, sulphur dioxide, brine, and so on—with high accuracy.

In developing more perfect methods, expansion is often a factor; for example, in aviation the cracking of spark plugs in the motors restricted the consecutive flying time. Expansion was the vital problem—ideal spark-plug materials would expand alike—and research developed a new formula for spark-plug porcelain to match the metal expansion and not crack with the rapid and intense temperature changes to which a spark plug is exposed.

Fundamental determinations of the heat-conducting power of materials are very important, so that proper selections of materials to retard or enhance heat transmission may be made.

The transmission and reflection of *radiant energy* are known to vary with the wave length and kind of material; just how they vary has been the subject of many

researches. One of these researches gave the solution to the problem of keeping heat out of tents, and a simple test verified it. White canvas tents with plain outer surface, painted on the inside, with aluminum paint, will keep out 80 per cent of the sun's heat which would otherwise be transmitted through the untreated canvas. Other applications of the principle along similar lines created a sensation among technical experts. It was found that metal paint would reduce the heat transmission through the walls and roof of a refrigerator car or an ice wagon 50 per cent. Attics can be kept cooler in summer and warmer in winter by painting the outside of the roof with asbestos or white paint, and painting the inside with aluminum paint. The heat is thus restrained from entering through the roof in summer or leaving it in winter. The building industry was interested to learn that for the same reason a radiator painted with aluminum paint is only 85 to 90 per cent as efficient as one painted with ordinary paint.

The transmission of some 60 kinds of special glasses, both for visible and invisible rays is known, so that the makers and users of glasses for optical or other purposes, can now select glasses opaque to harmful rays, or which transmit or absorb any special colors or rays, as desired.

Standardized saccharimeters, colorimeters, radiometers, sextants, cameras, microscopes, telescopes, etc., are also the application of optical principles which are based upon constants.

The data of the science of optics have become invaluable for the rapidly developing new science of *atomic physics,* for every different wave length tells something of the structure of the atom which produced it. It is now known that the structure of the atom can be learned and the frequency of radiation computed from a measurement of the energy referred to. The exploration of the

atom is one of the outstanding scientific accomplishments of the past two decades.

When the basis of *atomic weights* in chemistry was changed from hydrogen (H = 1) to oxygen (O = 16), chemists determined the relative atomic weights of these two important elements with the greatest care. The use of atomic weights in chemical analysis concerns technology, as the check of *composition* is one effective method of control of the quality of materials. Chemical constants are, therefore, essential in the consideration of standards of quality, as the composition of material so affects its properties that *analysis* is almost the first consideration.

How useful materials are, why they are useful, and how they can be made more useful, are pertinent questions to engineers and technologists. The physical and mechanical properties of matter as affecting mechanisms, how structures behave under stresses, how they bend and stretch, and how designs can be perfected for best service—are all the subject of experimental tests and comparison with standards.

The value of the relation between *electrical* and *mechanical energy* is involved in many transactions in which electricity is concerned.

Accurate and authoritative values of these constants are just as essential as are those of standards of measurement. Their determination involves the most difficult and precise work in physics and chemistry, a fact not generally known by those not engaged in the scientific or technical work in which these constants are used.

### 3. Standards of Quality.

Specifications for material (by description, sample, or both), known as standards of quality, fixing in measurable terms a property or group of properties which determine the quality.

The numerical magnitude of each constituent property pertinent to the quality involved, and specific magnitude in units of measure of such significant factors as uniformity, composition, form, structure, etc.

**Purpose:**

To secure high utility in the products of industry by setting an attainable standard of quality;

To furnish a scientific basis for fair dealing to avoid disputes or settle differences;

To promote truthful branding and advertising by suitable standards and methods of test;

To promote precision and avoid waste in science and industry by affording quality standards by which materials may be made, sold, and tested.

Standards of quality, or purchase standards for materials, usually take the form of *specifications*, or definitions of their characteristics, including of course, the measurement of the specified properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, or a paper or cloth is found by use to be good or poor. The questions then arise, "Why is it good or poor?" "What are the physical or chemical properties or the particular combination of elements which make it of good or poor quality?" "How are its properties to be measured or its constituents determined?" These are questions for the laboratory to answer and involve physical and chemical investigations of the most difficult character.

A standard of quality for a given material may sometimes take the form of a *standard sample* of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort, except for color, finish, texture, etc., which are frequently specified in this manner for want of a better method. A standard sample is resorted to only in the

absence of definite and reliable specifications in terms of measurable properties.

Standards of quality necessarily take into account the purpose for which the material is to be used. To set the standard too low, results in losses, poor efficiency, or even danger to life; to make it too high may have the same result. That is to say, the material must be suitable for the purpose intended, due consideration being given to its *net utility.*

Standards of quality are intended to aid the purchaser or user of materials to secure the material best suited for the intended purpose by specifying it in terms which the producer can not mistake. A proper and adequate specification includes the necessary tests to ascertain whether the material supplied is in accordance with the requirements. Standardization of quality is such an important subject that it will be considered in detail in Chap. VI on Standardization of Quality; Specifications.

The time is not far distant when it will be required that all articles bought or sold shall be as represented, but it should be kept in mind that it is impossible to check quality, except in the case of those articles for which standards of quality and methods of test have been developed. It should not be assumed that the manufacturer is the party principally benefited by the development of such standards; on the contrary, the purchaser and user are very much affected by all things which affect the quality of the product.

**4. Standards of Performance.**

Specifications of operative efficiency or action for machines and devices, known as standards of performance, specifying the factors involved in terms susceptible of measurement.

Numerical statement of speed, uniformity, output, economy, durability, and other factors which together define the net efficiency of an appliance or machine.

**Purpose:**

To clarify the understanding between maker, vendor, buyer, and user as to operative efficiency of appliances and machines;

To make exact knowledge the basis of the buyer's choice;

To stimulate and measure mechanical progress.

Specifications for standards of performance must be set also for devices. These may include, in part, ships' watches, sextants, dry cells, weighing scales, rubber tires, automobile brakes, elevator interlocks, signal glasses and lamps, chemical glassware, milk-test apparatus, electric transformers, electron tubes, radio sets, etc.

In drafting such specifications, research data from experiments may include any or all of the following: (*a*) listing the functions to be served, (*b*) measuring the elements which serve each item of use, (*c*) setting the 100 per cent efficient performance, (*d*) defining a commercially acceptable standard, (*e*) devising means to measure each factor pertinent to the service, (*f*) drafting specifications for performance, or (*g*) making such specifications available to the producer and the consumer.

The items of *acceptable performance* are most varied—speed, economy, accuracy, efficiency, durability, and many others. The breakage and wear of a hacksaw, for example, depend on the steel and on the design of teeth and frame. To specify its useful life and cutting rate is to set a standard of performance, or work value, or utility factor. A performance may involve speed; for example, the photography of a bullet in flight in one-millionth of a second, or an effective profile of a propeller or airplane wing. The performance standard may involve: (*a*) continuity, as in the non-stop run of a motor; (*b*) uniformity of rate, as in a timepiece; (*c*) efficiency, as in the gasoline motor; (*d*) economy, as the luminous efficiency of the electric lamp; (*e*) accuracy, as in a

thermostat; and so on. If fixed in units or measurable terms, these are standards of performance. Their use and application require judgment based on experience and experiment, a knowledge of physical and chemical constants of materials and energy, and a correct use of the principles of science.

Two distinct types of performance standards may be recognized: (1) a scientifically ascertained theoretical maximum; and (2) a commercial standard of acceptable performance based on what can reasonably be expected of industry in the present state of the art. A perfect motor could not exceed a known theoretical maximum and the actual performance of motors is rated as a percentage of this. A most valuable aspect of such an ideal standard of performance is that it gives the goal—the ultimate limit. This is not attained in practice, but it stimulates progress; for example, the mechanical equivalent of light has been ascertained as about 50 candles per watt. An ideal standard of performance would then be an unattained conversion of electricity into light at the rate of, say, 1 watt input for 50 candles of light output. Industry produces about 2 candles per watt. Such absolute standards are determined by scientific research. They stimulate and measure achievement, for they point to further progress theoretically possible by which the standards approach the attainable limit. Researches add such data which become permanent working factors in industry. These have proved so productive that science and industry will doubtless encourage the complete formulation and use of standards of performance for all tools and devices used in science, industry, or other activities. Such *standardization* is under way in all industry.

Metals play an important part in industry. Science is applied to the preparation and use of *metals* and *alloys*, to discover new ways to test their useful behavior, to purify

them, to mitigate their corrosion, and to perfect their structure by heat treatment; in short, to make metals already vital to industry more useful and durable. Failures are studied under standardized conditions; their causes are located and remedies suggested. Improvements in standard methods and appliances for the investigation of metals are continually being developed.

"What gives cloth unusual strength?" "What makes paper durable?" "How fast does sole leather wear out?" "How quickly does concrete set and what load can it bear?" and "What makes metal glazes adhere?" are questions answered by measuring appliances which indicate in units derived from standards, just how effective, strong, and durable the materials are. Science and technology tell an exact story of how materials such as rubber, leather, paper, yarn, cordage, fabrics, glass, cement, lime, stone, etc. behave, and how they can be improved. Better ways to investigate, specify, and test the useful properties of materials and better methods of making and using them are continually being developed.

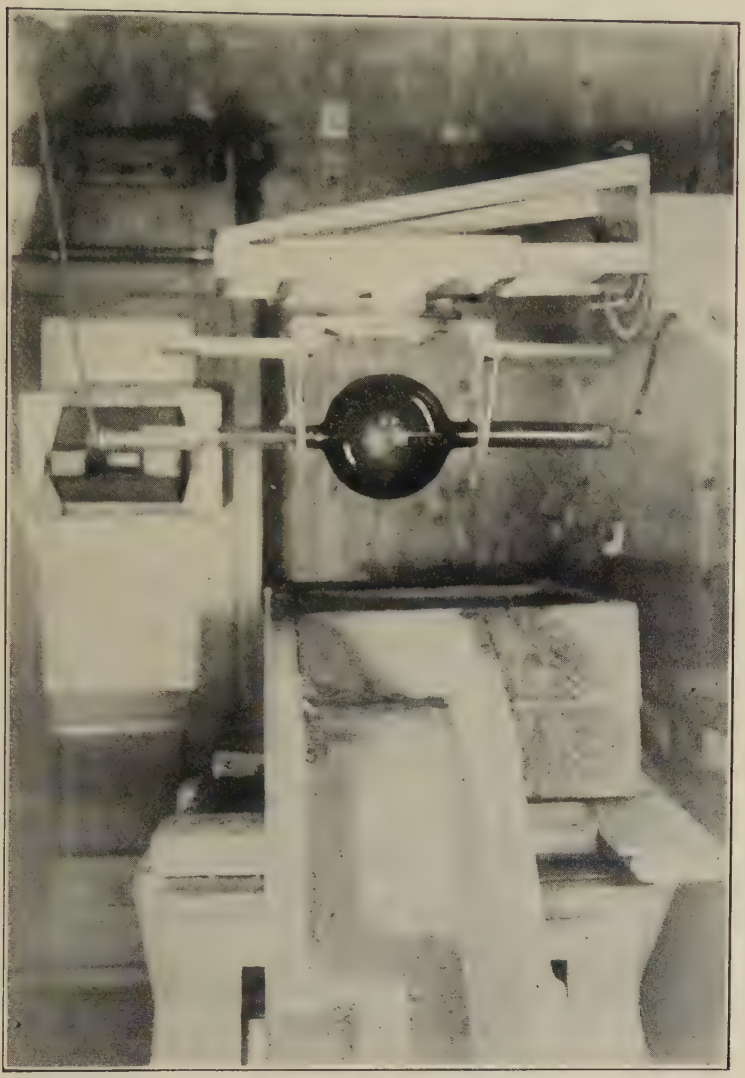
Standards must be known precisely for application to the processes of industry. Linear dimensions are important, but, in recent years, measurement of the *properties of materials* has attained a superior importance.

**Industrial Application of X-rays.**

The X-ray examination of metals is a recent engineering application of a scientific principle to new fields.

With the hope of preventing the acceptance into the military service of unsound metal components and of assisting the ordnance designer to meet service requirements in regard to lightness, a 280,000-volt X-ray equipment was put into operation in the laboratories at Watertown Arsenal of the Army in September, 1922.

To insure protection to persons, the room in which the equipment was installed was lined with lead ¼ inch



*(Photograph furnished by courtesy of the Watertown Arsenal, United States Army)*

FIG. 7.—X-ray tube arranged for radiographing a portion of floor frame of a 16-inch Coast Defense gun.

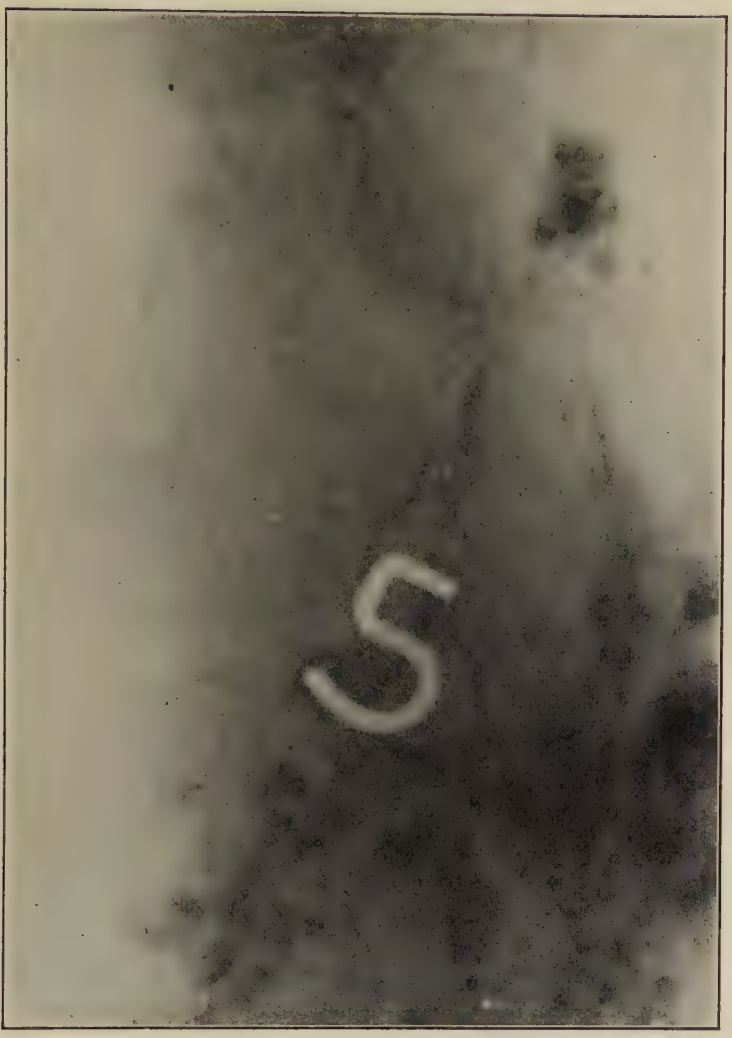
thick and all joints and securing screws were similarly covered. A lead-lined periscope permits the operator to view with safety the Coolidge tube when making an exposure.

When about 200,000 volts are impressed on the Coolidge tube, an exposure of about 1 minute is required for a 1-inch thickness of steel, about 5 minutes for 2 inches, and about 30 minutes for 3 inches (Fig. 7). Efforts to obtain clear negatives up to 250,000 volts impressed on the Coolidge tube with a thickness of steel much in excess of 3 inches have not been successful.

The experience so far had with the equipment has demonstrated that it has great practical value in showing the methods by which sound steel castings can be produced, and as an instrument of inspection.

It is the practice at the Watertown Arsenal to make one casting from each pattern, which is X-rayed. As the negatives, when properly interpreted, reveal the character, size, and location of all defects, it has generally been found possible by changes in method of molding, location of risers, etc., to obtain castings free from defects or to locate them where they do no harm. If the method of molding is changed, one or more castings made in accordance with the change are X-rayed to verify the accomplishment of the object desired, and a certain percentage of those regularly made are also X-rayed for verification.

The removal of all defects or their location where they do no harm enables a material saving in the weight of castings to be made. The cost of making X-ray negatives of castings is far less than the cost of cutting up castings to ascertain their *soundness*. The loss of the cost of machine work performed on castings subsequently rejected for revealed defects has been practically eliminated. Users of steel castings will appreciate the saving that results from the practical elimination of lost



*(Photograph furnished by courtesy of the Watertown Arsenal, United States Army)*

FIG. 8.—Shrinkage cavities.

*Radiograph* showing shrinkage cavities, known to the foundry man as *pipes*. These are caused by shrinkage of the metal at time of solidification. The numeral 5 that appears in the cut served merely to identify the area on the casting through which the picture was taken. There was a corresponding numeral painted on the casting. The dark portions are cavities.

castings that have been partially or wholly machined, and from the reduction in the weight of steel castings. It is considered that the experience had with this equipment justifies the Ordnance Department of the Army in adopting it as part of its regular inspection apparatus.

Those X-rays which pass through a cavity, and, therefore, through a less thickness of metal, reach the photographic plate or film with greater intensity, therefore causing a dark spot in the radiograph, the outline and size of the spot corresponding closely to those of the defect, (Fig. 8) which in this case is a "pipe," caused by the shrinkage of the metal at the time of solidification.

The experienced operator can tell from X-ray pictures of steel castings the location, approximate size and shape, and, with considerable certainty, the cause of defects. Occluded sand, cavities formed by gases entering the metal during solidification from the core and mold, piping or shrinkage cavities resulting from inadequate feeding from risers during solidification, cracks caused by unyielding cores or failure promptly to relieve the mold, welding and imperfections in welding and burnt-in metal, can be individually detected.

A constructive use of the knowledge obtained from X-ray pictures of castings enables articles to be designed and methods of molding to be used that either produce sound castings or locate defects where they do no harm. The production of such castings reduces to a minimum subsequent rejections.

The World War did much to broaden the *industrial application* of X-rays. The British Army developed a system of examining airplane timber to a depth of a foot or more to detect hidden knots, resin pockets, bad gluing, and poor, concealed workmanship. Carburetters and oil feed pipes were examined for defects and obstructions.

Better automobile tires are made by at least one firm because of its application of X-rays to detect imperfect union between rubber and fabric, and excessive stretching of canvas. Electric welds are tested for soundness, and coal is X-rayed for ash-forming mineral matter.

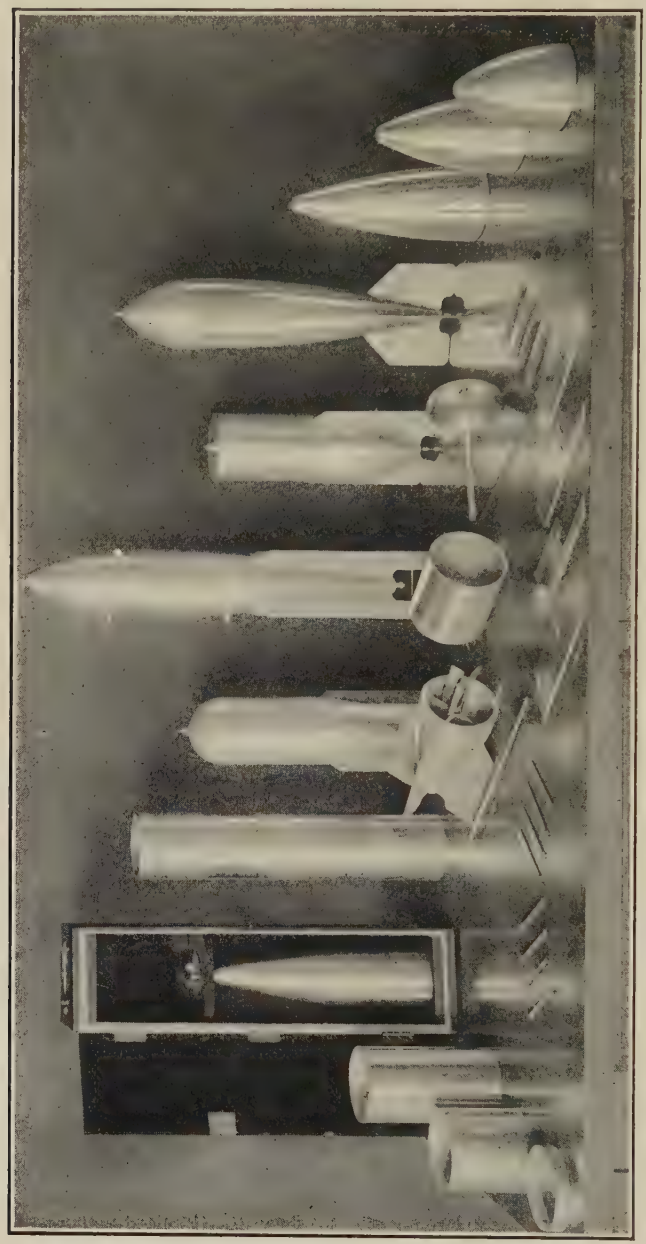
As the newest industrial tool for inspection, the X-ray represents perhaps the most revolutionary factor in the present situation in metallurgy, as well as in other industrial arts.

The use so far made of the diffraction X-ray equipment in the Watertown Arsenal laboratories shows that it is possible to determine what elements, solid solutions, etc. are present in metals, to determine the geometrical figure in which the *atoms* of each element, solution, etc. are arranged, and the distance between the atoms, both with a sample stressed and unstressed. The results so far obtained justify the prediction that our knowledge of metals will be wonderfully increased by the results obtained from this equipment. The diffraction apparatus shows changes in *fundamental structure* caused by (*a*) cold working, (*b*) heat treatment, and (*c*) alloying with various metals. Changes in structure thus obtained should be correlated with physical properties determined by physical test.

Existing law requires the laboratories at the Watertown Arsenal to make tests of iron, steel, and other materials used in constructions requested by citizens at actual cost to them. The use made of the laboratories under this law by manufacturers and vendors in this country has been very pleasing to its management.

**"Streamline" Designing Based upon Scientific Tests.**

A knowledge of air flow around objects is important in many fields of design and operation. What forms move through fluids with least resistance are easily determined, experimentally, by comparison with results



(*Photograph furnished by courtesy of the National Bureau of Standards*)

FIG. 9.—Types of projectiles and bombs which have been tested aero-dynamically to determine the most effective *streamline* profile to lessen air resistance. The same principle is applied to the design of ships' hulls, airplanes, dirigibles, submarines, racing automobiles, and, in some instances abroad, to the design of boiler fronts of locomotives hauling high-speed express trains.

obtained with standardized forms. The results of *aerodynamic* and *hydrodynamic tests* show that the most effective "streamline" profiles for projectiles, falling bombs, airplanes, airships, ships, submarines, and so forth, have a greater radius of curvature at the rear than in front (Fig. 9).

The shapes of ships, automobiles, and railway trains do not always have the best streamline designs. We wish to travel fast with as little power as possible, but we do not always select the best shapes for speed. It seems logical enough to make a prow sharp—something that will cut the water or air like a knife. But the wind tunnel and the towing tank prove that sharpness of prow is not an aid in attaining speed. Ducks and other swimming birds, fast fish, and such swift flyers as the albatross, are rounded and blunt in the breast or the head—the part that cleaves water or air, as the case may be. Nature developed streamlining long before man appeared on the earth, and, streamlining is the secret of speed. All her fast air and water travelers have evolved on lines which agree with modern scientific knowledge. A swift bird on the wing always draws up its legs close to its body and stretches its neck as far ahead as possible. Instinct teaches it to reduce its *projected area*, as engineers call it. The lesson taught by the high-speed bird is so patent that airplane designers have actually tried to build machines that would fold up their landing gear in flight.

There is a practical lesson to be learned from racing automobiles, speed boats, and record-breaking airplanes. If automobiles and railway trains that will travel faster, or with less power than is now possible, are to be attained, their edges and sharp angles must be smoothed off. It would seem that a railway train might be better streamlined. The ideal condition would be to have it as "smooth as an eel" from engine to rear end.

With this object in view, the boiler fronts on the locomotives of some high-speed European express trains, particularly those on the *Paris, Lyons, and Mediterranean Railway*, and the *Italian State Railways*, have a conical form to lessen air resistance.[1]

Tests have shown that at 60 miles per hour, about half of the power of an automobile or train is used to overcome air resistance, and the relative air resistance increases very rapidly with further increase of speed.

### Control of Railway Track Scales.

The National Bureau of Standards operates two railway track scale test cars (Fig. 10), which are used to test the master railway-track scales of the entire country. They are also occasionally used to check the test cars belonging to the railways. These cars are of special design, with an electric crane, the current for which is generated by a dynamo operated by a gasoline engine. The car is also equipped with a motor-driven truck of known weight, upon which standard weights can be loaded. Weights of 50, 2,500, and 10,000 pounds (105,000 pounds in all) are carried in each car.

By this means a *fundamental control* is exercised over the weighing of all heavy railway freight shipments of the country, amounting to approximately $4,000,000,000 per year.

### The Value or Utility of a Machine Depends upon Performance.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms which are correct and susceptible of measurement. As in the case of standards of quality,

[1] Private communication from the *Commission permanent de l'Association internationale du Congrés des Chemins de fer*, Brussels.

*(Photograph furnished by courtesy of the National Bureau of Standards)*

FIG. 10.—Railway track scale test car. Operated by the National Bureau of Standards for checking the railway track scales of the entire country to insure accuracy of freight charges.

the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether the specification or guarantees have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the method used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To do this properly involves the use of standards of measurement, standard values of constants, standards of quality, scientific investigations, and a knowledge of technical and manufacturing processes.

**5. Standards of Practice.**

Codes and regulations impartially analyzed and formulated after study and experiment into standards of practice for technical regulation of construction, installation, and operation, and based upon standards of measurement, quality, and performance.

Collation of standard data, numerical magnitudes, and ranges of the pertinent factors defining quality, safety, economy, convenience, and efficiency.

**Purpose:**

To furnish for each utility a single impersonal standard of practice as a basis for agreement of all interests, clearly defined in measureable terms;

To insure effective design and installation of utilities of all kinds;

To promote safety, efficiency, and convenience in the maintenance and operation of such utilities;

To secure uniformity of practice where such is practicable, and effective alternates in other cases.

Standards of practice are generally involved in the enactment of laws when technical and scientific matters are concerned, in the ordinances relating to the regulation of public utilities, and in the establishment of building and safety codes.

*Safety codes* cover the most hazardous occupations. The more complex standards of practice are illustrated by the national codes for *electricity, gas, aeronautics, lumbering, lightning protection,* and *elevator practice.* These are well-developed expert proposals and have authority only as embodied in rules of public utility commissions or local governments. Safe conditions are strictly made to measure; the thickness of a conducting wire or its insulation, the load capacity of a fuse, the stopping distance of an automobile brake, the voltage of a circuit, the pressure on a safety valve, the percentage of injurious gases allowable in household gas, the flash point of oils—these and thousands of others are made safe by safe limits set in units of measure. Uniformity of practice is promoted when a single national standard is available as a model.

In automobile headlight practice, the illuminating engineers drafted specifications to define acceptable performance of automobile headlights. These were based on tests and researches over a series of years. Approved by the American Engineering Standards Committee as tentative American standards, they sum up good road practice. They have authority only as put in local laws or rules. If applied, they assure safety, comfort, and speed on streets and highways.

Safety codes are dependent upon standards of performance, and like the latter, are also dependent upon standards of measurement and standards of quality. Safety codes are of the most vital importance in questions pertaining to the welfare and safety of the public.

The trend is clearly toward a single national service standard for every distinctive use, exactly as we have a single national standard of length. The importance of a single standard of length has long been recognized; the importance of a single service standard for each material, device, or practice is beginning to be realized and made the basis of effective standardization.

**Importance of Standards to the Purchaser and Consumer.**

Weights and measures are matters of national control, like the currency. All nations so regard them. The writers of the Constitution which gave Congress power to "fix the standard of weights and measures" could not have foreseen that measures would have to be provided for heat, electricity, radium, light, and radio; yet today the calorie, the watt, the curie, the candle, and radio frequency or wave length, are as needed in modern industry and trade as are the yard, gallon, and pound.

Commerce and trade are five-dimensional arts, and involve *quantity*, *quality*, *value*, *place*, and *time*. All of these factors are measurable: quantity in unit and number; quality in magnitude of pertinent properties; value in terms of a standard weight of pure gold; place in terms of latitude and longitude, or place name; and time in terms of the rotation of the earth (the clock) and its revolution around the sun (the calendar). *Buyer and vendor* agree on these *measurements* in the *market*.

In other words, everything made, bought, sold, or used, is measured, or compared with standards, at some stage of its existence; not only is its *quantity* determined, but its properties are measured to ascertain its *quality*, and the latter then evaluated with *price*, to determine its *value*.

Three factors especially, namely, quantity, quality, and price, enter into every *commercial transaction*, and no

transaction can be on a satisfactory basis until they are expressed in definite and measurable terms. With this in mind, the great importance of standards and measurements is readily apparent.

Standards control what the buyer gets—length of cloth, volume of gas, or weight of coal. Whether measured on the counter or in a staple package, commodities are bought by measure. Standards are used to check the *cubic-foot* standard for the maker of gas meters, the *troy pound* for the coinage, the *inch* of the factory, the *avoirdupois pound* of the grocery store, and the *gallon* of the filling station. Correct measures, qualitative and quantitive, should be back of every transaction in trade and commerce.

## CHAPTER IV

## STANDARDIZATION

### GENERAL CONSIDERATIONS

As a basis for understanding and differentiation, it seems desirable, at the outset, to define standardization.

Standardization may be defined as the unification of the methods, practices, and technique involved in the manufacture, construction, and use of materials, machines, and products, and in all lines of endeavor which present the necessity for performing repetition work. From the viewpoint of the buyer and vendor, it is the establishment of a *criterion* for the dimensions, quality, or performance of those materials, machines, and products. In its former aspect, it tends to assist scientific and engineering development and to prevent waste in manufacturing. In its latter aspect its purpose is principally to assist in promoting a common understanding between producer and user.

Standardization primarily means *the setting up of standards* by which extent, quantity, quality, value, performance, or service, may be judged or determined. It is the crystallization of the best thought and practice of industry, business, or art into definite forms for general usage.

A standard under modern scientific management is a carefully drawn description covering the necessary characteristics of a material, a machine, or some article of stores or product, or a method of performing a function. Such a standard is simply the best that can be devised at the time and covers all the points of variation

which it is possible or desirable to consider at the time the standard is set up.

Improvements in standards are desired and are adopted whenever and wherever they are found. There is absolutely nothing in standardization to preclude *innovation;* but in order to protect standards from changes which are not in the direction of improvement, certain safeguards are set up to protect them from change for the mere sake of change.

All that is required under modern scientific management is that a proposed change in a standard be scrutinized as carefully as the standard was scrutinized prior to its adoption; and, further, that this work be done by experts as competent to do it as were those who originally adopted the standard.

Standards adopted and protected in this way provide the best that is known at a given time, and standardization thus practiced is a constant invitation to experimentation and improvement. *The idea of perfection is not involved in standardization.*

It is quite easy to set up a standard, but it is altogether another thing to get that standard widely adopted, and a standard which is not in accordance with the fundamental needs of industry, that is, which does not fulfill a recognized want, is economically a bad one.

Any standard, to achieve its object, must be suitable for the intended use of the thing to which it applies in the majority of cases; the exceptional case requires special consideration, and actual perfection and complete uniformity will never be attained. The economies and benefits of standardization as applied to the materials, processes, and products of industry have been so thoroughly demonstrated within the past few years that they are entirely outside the argumentative field.

Modern industrial standardization is dynamic. It is arrived at by continuous research to establish in units

of measure an evaluation of the several factors which will give the *maximum feasible utility* to materials, devices, processes, or products. It also includes the establishment of allowable variations from specified measurements, liberal enough for economy of production and close enough for efficient functioning and effective interchangeability. In the final step, the interests of various industrial concerns are considered in order to obtain an acceptance of the standard in commerce.

**Application of Standardization.**

Standardization may be applied in individual industrial plants, or in entire industries. Individual manufacturers may standardize their own products and processes, yet such individual standards may not become accepted standards of general usage. With individual standardization, there is confusion on the part of the buyer as to what is standard, caused by a multiplicity of so-called standards confronting him. Nevertheless, individual standardization is helpful in improving general quality or value of a given article or commodity, and expediting development of a superior, or more nearly *ideal*, type of that article. Best results, however, are secured when all interests cooperate in the work of standardization, and contribute to the development of standards. *Manufacturer, distributor, and consumer* are each entitled to a voice in the proceedings in order that the final standard proposed for general adoption and use may represent the best current practice.

Standardization is currently used in two wholly different senses which should be carefully distinguished: (1) the prescription by law, and the supervision and enforcement by legally constituted authorities, of the elementary units and standards of length, capacity, weight, and money, on which industrial and trade operations depend for their security and convenience, together with such

other standards of purity, strength, or quality as it may be considered necessary to enforce in order to protect the health, safety, and well being of the people; (2) the voluntary determination and adoption by producers and users, either individually or in agreement, of desired standards of type, grade, size, composition, or other characteristics, with a view to attaining some measure of uniformity, in order to eliminate the waste caused by the unnecessary variety of products, and to insure the interchangeability of parts.

Industry and trade are deeply interested in both of these kinds of *standardization*, but the interest is of a wholly different nature in the two cases.

### Compulsory Standardization of Weights, Measures, Money, Etc.

The *fixing by authority and enforcement* of standards of length, capacity, weight, time, money, quality, purity, etc. is universally regarded as one of the elementary functions of the governments of all civilized countries, and it is evident that, unless they discharge this function with efficiency, modern industry, trade, and commerce would be seriously affected.

### Voluntary Standardization.

Industrial standardization, in the second sense of the term, is the *voluntary fixing* of standards of dimension, quality, etc., by the interests concerned, with the object of having *definite* standards and a limited variety of products in use, and by this means eliminating waste of labor, material, and capital, and so reducing the costs of production, distribution, purchase and use.

It is evident that the mere legal fixing and enforcement of fundamental and secondary units and standards, though an indispensible prerequisite of industrial standardization, does not of itself tend to reduce the variety

of types, grades, sizes, finishes, etc. of products in use. Nor does the legal fixing of standard requirements of purity and quality have more than an indirect effect in this direction. No doubt, for example, the *pharmacopoeia* controls the purity of drugs, and has some tendency to restrict the variety of drugs and prescriptions, but, generally speaking, legal standards of purity and quality are *minimum* requirements, from which unlimited variation is allowed in an upward direction. In order to ensure an effective reduction of the variety of products and thus to realize the economy which is the object of *industrial standardization*, something more than this is needed, namely, agreement to adhere to *definite* standards from which deviation in *neither* direction is permissible.

The growth of the modern system of production by elaborate machinery on a large scale tends powerfully to encourage standardization by familiarizing manufacturers and consumers with the cheapness and consequent economy resulting from the *mass production* of articles of uniform type, grade, size, etc. But while mass production is commonly associated with standardization, the specific economies resulting from standardization are quite distinct from those arising from large-scale industry, nor are its benefits by any means applicable to all such industries to an equal degree.

Standardization in the sense now under discussion is applied, through voluntary agreement of those concerned, to many departments of commerce and industry, and even to art, as exemplified by the establishment of a definite *concert pitch*, for the tuning of musical instruments; and to *sports*, as when the limit of size or weight of tennis balls, golf balls, base balls, etc. is prescribed.

In the marketing of certain varieties of natural produce (wheat, cotton, etc.), recognized *grades* have been established for the convenience of vendors and

buyers and to facilitate market operations generally. It is, however, in connection with the manufacturing industry that standardization has its chief application. In these days, when standard screws and bolts for replacement on ordinary machines and appliances may be bought from any hardware store, it is difficult to realize that prior to the early part of the nineteenth century *screw threads* were in the main cut by hand by chipping and filing, every screw was different from every other, nuts and bolts had to be paired by special fitting, and replacement, in the ordinary sense, was impossible. It was not until efficient machines for making screw threads in quantity had been devised and constructed that it became possible to effect the standardization of these articles.

Standardization may obviously be adopted either by individual manufacturers, each of whom may have his own pattern or specification; or, alternatively, all or some of the manufacturers of a certain article may agree on the standard which they will employ, the result being that they all produce substantially similar products. While the full advantages of standardization from the point of view of the manufacturer, dealer, and user can, as a rule, be obtained only by the general adoption of standards, considerable advantages and economies can be secured by the use by individual manufacturers of their own *standards;* and this applies even in comparatively small works not operating on a so-called *mass production* scale, *i.e.*, those operating on a scale which does not depend fundamentally on the use of specialized machines. In addition to the mechanical advantages involved, this individual standardization renders possible proper cost systems and proper work-progress sheets and routing systems. While standardization thus has advantages even in small-scale production, it frequently becomes essential when *mass production* is involved

and where parts are produced on special-purpose machines. To a considerable extent, standardization automatically follows the adoption of such production methods. The assembly shop could never cope with its task if it were burdened with either *fitting* or *selective assembly*. Examples of articles manufactured by these methods are the watch, the automobile, the sewing machine, the typewriting machine, firearms, etc. The product of mass production, based upon the standardization of the complete article and its components, must permit assembling, disassembling, and reassembling of the respective parts taken at random.

The fact that *mass production* is generally associated with *standardization* has resulted in a tendency to credit to the latter all of the cost reductions which are rendered possible by large-scale production. The two economies are distinct, however, and it should not be assumed that standardization alone can secure the advantages derivable only from production on such a scale as to justify the installation of special purpose tools and machines. It is even quite possible that under some circumstances, mass production may necessitate departure from the general standard, and that the existence of one or more individual large manufacturers who have adopted standards of their own may hamper or prevent the adoption of standards by the whole industry.

It should be pointed out that standardization is not necessarily practicable or desirable in all branches of manufacture. For example, change and variation from the standard are often essential in order to gain or retain some foreign market, and standardization is, therefore, probably more difficult to apply to the full extent when industries are producing goods for export to various parts of the world, each one of which may have its own necessary or customary requirements, than when they are working mainly for a large domestic market.

Again, in the case of goods (*e.g.*, some classes of textiles) where *style* and *artistic quality* are important features, the makers must necessarily give consideration to the variations of taste and artistic standards, not only as between one country and another, but as between individual buyers in the same country, and the application of standardization to such products is consequently subject to considerable limitations.

**Advantages of Standardization.**

The advantages of standardization in reducing industrial costs to both producer and consumer are many and important. The decrease in variety reduces the number of interruptions in production due to changing the *set-up* from one product to another, and the assembling and replacement of parts are greatly simplified by interchangeability. The fixing of standard *types* makes the installation of labor-saving devices economically possible and encourages continuity of production by making it safer to manufacture for stock. It also diminishes *capital investment* in plant, equipment, and materials, and materially reduces the cost of distribution by decreasing the stocks of different varieties which the distributor is required to carry. Effective standardization also simplifies the task of the purchasing officer, and promotes competition, as he is not limited to the products of any individual manufacturer.

On the other hand, there are certain dangers in *over-standardization* which deserve careful consideration. Briefly stated, the dangers are:

1. That standardization may *crystallize* existing practice and ultimately retard development.

2. That it may be carried to a point incompatible with the maintenance of high quality or artistic excellence, and inconsistent with ready adaptation to meet the local needs and taste of different markets.

The first of these dangers is, perhaps, on the whole, the greater. Cases might easily arise in which a branch of trade, having an established standard might oppose the introduction of a desirable variant or alternate of that standard, for fear that the resulting competition might be prejudicial to its interest. If this kind of sectional obstruction were allowed to prevail, standardization would be prevented from making any progress, and if it is to be avoided or overcome it is essential that the standardizing authority be strong and independent, and not at the mercy of any sectional interest.

The second danger, incompatibility, may influence the adaptability of products, and is one that needs to be very carefully borne in mind by any standardizing authority.

The elimination of a useless multiplicity of products is not necessarily prejudicial to quality and artistic excellence, provided that the reduction of variety is carried out with wisdom and discretion. The restraint resulting from the limitation of variety of products is often more conducive to beauty than the multiplicity arising from unrestricted freedom of choice.

Standards set up after the fullest consultation with users have sometimes failed to secure wide adoption, owing to the reluctance of buyers and users to depart from established customs. Standardization can make permanent progress only if users realize that it presents advantages to them as well as to manufacturers. It should be remembered that *standardization is a means and not an end.*

**Object of Industrial Standardization.**

Industrial standardization has for its main objects the elimination of waste of *time, material, and labor*, and, therefore, *capital*, involved in the production of manifold types, qualities and sizes, of articles for one and the same

purpose; the fixing of the dimensions of component parts where interchangeability is necessary; and the setting up of standards of performance whereby comparisons can be made with equity, as well as the defining of attainable quality of material, which also involves standard tests. Rapid and economical production may certainly be claimed as one of the leading benefits, and the securing of this is not only advantageous to the manufacturer but also to the consumer in the rapidity with which his orders can be filled from stock, the ready replacement of damaged and worn parts and, not infrequently, the reduction in selling price.

Standardization is the modern way of perfecting methods and services. Even the skill and efficiency of the artisan are standardized in motion studies as taught by Marey and Gilbreth, and are portrayed graphically by wire models. Time and motion studies in industrial operations are recorded in measured time sequence by the photocyclochronograph and high-speed camera, and are then reproduced in three-dimensional graphs for study.

Intelligent standardization presupposes, in the first place, definite knowledge of the departmental conditions of a business; necessitates, in the second place, a reconciliation of adjustable qualities and sizes; and involves, in the third place, a certain amount of educational work within the departments of an industry, looking toward the sympathetic adoption of standards representing their integrated needs. Each of these procedures is inseparably related to the others and involves in itself a number of collateral studies to determine the proper balance between *quality* and *utility*.

Under the modern factory system of production, with its large-scale enterprise and minute subdivision of tasks, there is a progressively increasing resort to standardization of processes and of products in the satisfaction of *economic wants*.

*The basic advantages of the modern division of labor*—the best utilization and development of human capacities and the continuous employment of men and machines in the performance of specialized tasks—can be fully realized only when all industrial operations are made as uniform and simple as possible. This means *standardization of processes*. But such standardization of industrial technique generally involves large-scale operations, mass production, and the fabrication of vast quantities of practically indistinguishable articles. This means *standardization of products*.

Standardization has been more discussed than almost any other topic in industry. It has been confused with much inaccuracy and many misconceptions. Many technical men have given but little attention to the subject, and business men have, in general, almost disregarded it. If the setting up of standards were difficult, or if the subject were in the cloudland of metaphysics, there would be less reason to wonder at all the debate and complexity; but the undertaking is inherently simple.

Every problem of standardization may be divided into the *technical side* and the *human side* and, in most cases, the human side is a large part of the total. The technical factors are usually so well known that, so far as these are concerned, it is a case of facts rather than opinions; but when we come to deal with the human side, it is largely a matter of opinions which sometimes are not in accord with the facts.

It should be remembered that standardization is really a science all of its own, and it is only gradually that its underlying principles have been understood and its great economic value has become recognized.

Standardization is synonymous with fitness to industrial conditions, and success in standardization involves two fundamental principles. One is a rational method of procedure in the formulation and adoption of a standard,

and the other is a practicable plan for putting new standards to work in industry.

On surveying industrial activity, one is impressed with the plethora of styles, grades, designs, sizes, measurements, shapes, colors, finishes, and so forth, both of completed articles and of semi-fabricated products, whose usefulness or capacity to yield satisfaction is in no way dependent upon these distinctive characteristics. Every producer, left free to gauge the unpredictable wants of consumers, is strongly tempted to try to meet or create a demand for a product which is in some respect or other, however negligible, *unique*. He thereby would assure himself, at least temporarily, an exclusive control of supply, with all the pecuniary advantage that flows therefrom. From the standpoint of the general public, however, this procedure involves economic waste.

**Modern Industry Based upon Standardization.**

The physical basis of modern industry is the *machine process* and the discipline of this machine process enforces a standardization of knowledge in terms of quantitative precision, and inculcates a habit of apprehending and explaining facts in terms of material cause and effect. It involves an evaluation of *facts, things,* and their *relations,* in scientific terms.

Modern industry has little use for, and can make little use of, materials, machines, and methods that do not conform to the adopted *standard.* What is not competently standardized calls for too much of craftsman's skill, reflection, and individual elaboration, and is, therefore, not available for economical use in industrial processes. Regularity in industrial products demands *standardization.*

The materials and products of industry are undergoing a reduction to staple grades; for example, lumber, coal, steel, rubber, oil, cordage, fibres, paper, wool, cotton,

grain, leather, etc. All these and many others are, to an increasing extent, bought and sold under well-defined staple grades as to quality and dimensions, weight and composition.

The same is true of complex products. Modern consumers, in large part, require commodities that conform to recognized standard specifications of type, size, and grade. The consumer (that is to say, the masses of consumers) furnishes his house, his table, and his person with articles of standard quality, weight, and measure, and he can, to an appreciable degree, specify his needs and his consumption in the notation of the usual standards. As regards the masses of civilized mankind, the idiosyncrasies of the individual consumers are required to conform to the uniform gradations imposed upon consumable goods by the comprehensive mechanical processes of industry.

Any manufacturing operation that can be reduced to uniformity, so that exactly the same thing has to be done over and over again in the same way, is sure to be taken over sooner or later by a machine. There may be delays and difficulties; but if the work to be done by it is on a sufficiently large scale, money and inventive power will be spent without stint on the task till it is achieved.

The power of machinery to do work that requires too much accuracy to be done by hand is perhaps best seen in some branches of the metal industries in which the system of interchangeable parts is being rapidly developed. It is only after long training and with much care and labor that the hand can make one piece of metal accurately to resemble or to fit into another; and, after all, the accuracy is not perfect. But this is just the work which a well-made machine can do most easily and most perfectly. For example, if agricultural machines had to be made by hand, their first cost would be very high; and when any part of one were broken,

it could be replaced only at great cost by sending the machine back to the manufacturer or by bringing a highly skilled mechanic to the machine. But as it is, the manufacturer keeps in store many duplicates of the broken part, which were made by the same machines and are, therefore, interchangeable with it. A farmer, perhaps hundreds of miles from any good mechanic's shop, can now use complicated, standardized machines with confidence, since he knows that by sending by mail or telegraphing the number of the machine and the number of any part of it which he has broken, he can promptly get a new piece which he can himself fit into its place. This principle of interchangeability of parts will ultimately extend the use of machine-made devices to every branch of production, including even domestic and agricultural work.

**Mass Production.**

The term *mass production* is used to describe the modern method by which large quantities of a single commodity are manufactured. Its primary reference is to *method*, but as commonly employed it is made to refer to the *quantity* produced. In several particulars, the term is unsatisfactory. Mass production is not merely quantity production, nor is it merely machine production. *Mass production*, in the modern industrial sense, *is the focussing of the principles of power, accuracy, economy, system, continuity, and speed*, upon a manufacturing project, with the result that *a useful commodity of standard design, workmanship, and material is manufactured at minimum cost. Mass production must be accompanied by mass consumption.*

Mass production is American in origin, and its earliest notable appearance in this country was in the first decade of the twentieth century. *Interchangeable* manufacturing is of French origin though developed success-

fully first in America. The mere massing of men and materials, however, is a procedure that was well understood by the Egyptian and Romans. Many of the basic industries, like weaving, domestic baking, house construction and wooden-ship building, are carried on essentially as they were in ancient times.

The effect of mass production on the product has been to give the latter the highest standard of quality ever attained in output of great quantities. Conditions of mass production require material of the best quality to pass successfully through the operations. The utmost accuracy must control all these operations. Every part must fit into the design for which it is made. In mass production there are no *fitters;* the necessity of hand fitting would indicate that the parts had been produced in a manner that makes them unfit for immediate placement in the article as designed.

In works of *art* and *luxury,* the desired accuracy is attained at the cost of careful *handicraft.* To introduce hand methods to obtain accuracy in mass production would render the latter impossible from a price standpoint. The standard dimensions of the product are guaranteed by the fact that the machines are so constructed, and the *set-up* is such that a piece of work cannot go through them unless it is in exact accord with dimension specifications. If the work goes through the machines, it *must* be right. Thus the burden is on management to design the article properly and select the materials from which it is to be produced by the multiple processes utilized in mass production.

**Difficulties of Standardization.**

The standardization of agricultural products is probably more difficult than industrial standardization because in practically every instance in agriculture *living organisms* are dealing with. No agricultural

commodity ceases to change the instant it is harvested, as does a manufactured product when it leaves the factory. This makes the problems somewhat more difficult, for a product that belongs in a certain grade today may belong to a different grade tomorrow. In many other ways the task is somewhat different from that of standardization in a manufacturing industry.

In agriculture, there are many thousand *manufacturing plants* to deal with. Everyone knows how difficult it is to standardize the products of even a few plants that are organized on an independent or voluntary basis. Moreover, in operating a manufacturing plant, barring a few difficulties, it is possible to manufacture to a set or established standard, but this cannot be done with certainty in agriculture.

Even with a so-called staple crop like cotton, the producer cannot decide at the beginning of the season just what *grade* of product he will produce. He cannot say that about so many million bales of this grade of cotton and so many million bales of another grade will be needed and then lay plans with any certainty to produce those grades of cotton in those quantities. Manufacturing plants can do that, but agriculture cannot.

Railroads are vitally interested in standardization, and attempts to standardize railroad equipment date back to the 'seventies, and was one of the largest functions of the Master Car Builders' Association and the Master Mechanics' Association (merged during the Railroad Administration in 1919 into the American Railway Association, Division V—Mechanical). Hundreds of definite *standards* and *recommended practices* have been adopted, covering many details, such as wheels, axles, bearings, couplers, hose, brake shoes, draft gears, rivets, bolts, nuts, lumber sizes, structural-steel shapes, air brakes, details of signaling and lighting

systems, and many other items. Recently the Association has adopted standard designs for the salient features of box cars, hopper cars, and gondola cars. It definitely standardized several types of passenger, freight, and switching locomotives and other cars of various types, but these standards were not received with much favor, and there is very little attention being paid to them at the present time.

A more scientific control over designs of the things manufactured, by a further standardization of articles and their component parts would mean an enormous reduction in the cost of manufacturing and assembling the articles and would make possible and profitable an *unbelieveable reduction in prices.*

With such *standardized designs,* repairs would also be made with standardized machine-made parts, instead of by hand fitting. This would result in incredible total savings, not only in costs of material, but in the time of the workmen and machines.

The maximum in machine production has nearly been attained in some industries. Further reductions in production costs will come largely through the elimination of wastes and the improvement of the product. The day of quantity for the mere sake of quantity is over; *this is the day of quantity with quality.*

Skyscraper cities, rapid transit, instant intercommunication—now visual—standardization, mass production, a standard of living for the majority possessed by not even kings in premachine days—these and more belong to us of this *Machine Age.* These ultramodern conditions of civilization have been made the subject of the Paramount picture "Metropolis,"—a German U.F.A. production—an exaggerated imaginative conception of what the machine age promises for the future. It is generally agreed, however, that there is little danger of the individual developing into a Robot.

**Classification of Standards by Use.**

Standards may be classified on the basis of their degree of acceptance, those in regular customary use being known as *standards*, while those in an initial or trial stage are known as *tentative* or *provisional standards*. In ordinary course, it is assumed that such standards will advance to the status of regular standards.

A further classification of standards is possible with respect to the time and trend of their utilization, thus, *obsolete*, *obsolescent*, *standard*, *prospective standard*, and *interim standard*, the latter being intended to bridge an interval between an obsolescent and a current standard, or between a standard and a prospective standard.

In an actively growing and developing industry, all of these classes of standards are often involved. Some may be designated as definitely obsolete, and others are to become obsolete after the lapse of a certain interval or upon exhaustion of existing stock. The third class, or active standards, is that for which no change of application is yet foreseen, while future or prospective standards may be established for utilization after a certain period of time or upon the completion of certain preparatory stages, or of related standardization work in other fields.

A fairly complete list of agencies engaged in standardization work in this country is given in the following table:

| | |
|---|---|
| 191 | trade and commercial associations. |
| 17 | professional and technical societies. |
| 54 | United States government bureaus. |
| 81 | state highway commissions and other state bureaus. |
| 105 | city government bureaus or departments. |
| 5 | national standardizing organizations. |
| 2 | American committees of international standardizing agencies. |

In Germany and in a number of other European countries which follow similar lines in such work,

standardization is divided into two major classes; *normalization* (*normung*), and *type standardization* (*typung*). The former corresponds in its leading characteristics to our *dimensional standardization*, which forms by far the largest part of standardization activities in continental European countries; the latter applies chiefly to the setting up of a planned series of standardized articles, usually on a dimensional basis, such as a complete series of paint brushes from the smallest to the largest sizes. This work corresponds in some respects to what is understood in the United States by *standardization of variety*, or *simplification*.

**Industrial Rationalization—The Elimination of Waste.**

A new word has been coined in Europe as a result of the recent (1927) World Economic Conference held in Geneva, to encompass the area of industrial and business technique upon which agreement has been reached. The word is "rationalization." Rationalization means, broadly, the reorganization of industry as a whole, and the elimination of waste. The term definitely fills a void in economic nomenclature, and encompasses the ideas of: *Standardization of materials, methods, and products; scientific management; the improvement of transportation, communication, and marketing; the consolidation of industries; stabilization, including the determination of the correct ratio between invested and productive capital*, etc., in fact, *the coordination of all business activities*. Rationalization originated in Germany, where it is credited with the formation of the steel cartel and the German-French potash agreement. There are organizations in France, Holland, Italy, Poland, Belgium, and Sweden, for carrying on the rationalization of industry. England is also showing interest in the new technique, and the United States is vigorously adopting the methods. It is a word that is destined to be heard more frequently in

this country. For further details on rationalization, in Germany, see page 179.

Objectors to standardization frequently urge that it stifles initiative and progress and that the adoption of a standard prevents advance through improvements in the arts of manufacture. Of course this is not the case. A standard should remain standard only until something better is developed, but it should not be changed until justified from all points of view.

Intelligent standardization presupposes a definite knowledge of the conditions of use of the material or article and a reconciliation of adjustable types, grades, and sizes. Standardization is largely a *compromise*, and must necessarily involve the sacrifice, in some cases, of personal preferences.

**Economic Importance of Standardization.**

Standardization of materials and manufactured products so as to facilitate *mass production, selling, and purchasing* is believed by engineers and economists to be the coming great principle in business and industry. In this country, for example, many important parts of equipment made by one manufacturer cannot be interchanged with similar equipment made by other manufacturers, due to lack of standardization in design.

With any large industry, standardization, and the resulting reduction of varieties of commodities to be purchased, stored and accounted for, offers a *fertile field for economy.*

Proper industrial standardization involves not only technical but economic and business considerations, and the data thus obtained must be submitted to executive decision based on the determined facts before standardization can attain the maximum possible results for both industry and the consuming public.

Although remarkable advances have been made in standardization of industrial technique by technical

men, the responsibility for further development lies largely with business and industrial executives.

Two major handicaps to the progress of standardization in this country are:

1. Industrial executives do not admit that standardization is an essential part of their business activities; they do not personally give it the attention it deserves, nor do they support a standardization program commensurate with its economic importance.

2. Past work in standardization has been delegated to engineering groups. It is somewhat unfortunate that engineering talent has heretofore dominated standardization work to the exclusion of business and economic considerations. This has obscured the fact that the major standardization projects are simply temporary running commercial agreements between manufacturers and users, and between buyers and vendors. Engineers and technical experts have a proper place in any standardization program but economic factors should be considered at least equally. Executive and commercial thinking must be introduced into the standardization movement in this country before maximum results can be obtained.

It is pertinent to examine how far standardization is tolerable, economical, desirable, and wise. Nothing in our modern civilization goes so quickly to the root of our ultimate destiny, philosophy, and politics of life as this matter of standardization. *The business executive must now answer some big questions:* To what extent is he willing to have industry standardized for the sake of the undoubted saving in time and money that it means to both producer and consumer?

The economic importance of standardization is not always fully appreciated. It has been estimated that about $8,260,000 was spent in 1926 for standardization work in the United States alone. This was divided about

as follows: Federal Government, $4,250,000; trade associations and technical societies, $3,820,000; and state governments, $134,000. The American Engineering Standards Committee spends about $60,000 a year.

The railroads, both individually and collectively through the various divisions of the American Railway Association, have done an immense amount of work along the lines of standardization. It would be difficult if not impossible to express numerically the annual cost of this work. The present highly efficient operation of American railroads would be impossible without the results attained by standardization. It is only necessary to recall the following: standard time; standard gauge; standardized materials; standardized equipment for line interchange; standardized structures; standardized operating rules, etc.

The economic results of standardization can be summarized under three general heads:

1. Systematizes Business.
2. Better Serves the Producer.
3. Better Serves the Consumer.

**1. Systematizes Business.**

Standardization expedites business procedures, shortens the time required for delivery, and stabilizes production, employment, and financing, making it safe to build up stock during slack times against future orders.

It furthers the tendency to put business undertakings on a systematic basis and eliminates purely traditional practices.

It tends to eliminate indecision both in production and distribution, thereby promoting efficiency and conservation of time, material, and energy.

The advantages of standardization are of mutual interest to both producer and consumer. A few of the possibilities are as follows:

*a.* Size, shape, style, and design.

*b.* Color, finish, brand, grade.

*c.* Raw materials, purchased parts, component parts, and fittings.

*d.* Performance, terminology, specifications.

*e.* Crates, cartons, containers, and labels.

Each of these items offers a field for profitable investigation and there probably is no industrial establishment wherein some application of standardization cannot be found.

**2. Better Serves the Producer.**

Products manufactured in accordance with standards that are nationally recognized reach a wide market through effective publicity that is given the standards during their development, the period of public criticism before their adoption, and finally by their adoption as standards. Standardization favors interchangeability of parts due to the higher accuracy of standardized manufacture, and so makes possible quick deliveries in adequate volume in emergencies. It assures prompt and satisfactory replacement of parts in making repairs, as fewer items have to be carried in stock; in emergencies such parts can be taken from other machines or equipment not in use at the moment.

Standardization enhances quality of product due to practical elimination of errors of manufacture and shipment resulting from increased and improved facilities for inspection and test, due to employment of improved tools, materials, and processes. This results in a reduction in the number of steps required and large saving in overhead expenses, the product at the same time tending toward lower and lower prices, relative to the prices obtaining on non-standardized products.

Standardization reduces investment in raw materials, semifinished and finished stock and repair parts, and

simplifies and renders less costly the maintenance, distribution, and inventory of stocks of materials, patterns, moulds, jigs, templates, tools, dies, gauges, instruments, and special machinery, as well as decreasing the storage equipment, personnel, and space required. It saves a multitude of diverse bids, bills, vouchers, payments, and receipts, due to the decreased variety and number of working materials used; and it permits the salvaging of standard parts from obsolete, rejected, or worn-out tools or equipment, with the result of minimizing losses due to stock depreciation and obsolescence.

By fixing good practice, it establishes quality and eliminates the burden of repeatedly designing new products and setting up of machines for the manufacture of similar articles which would be better, or substantially so, if identical.

It decreases unit costs by permitting mass production, thus reducing the number of changes and adjustments of machines required, and permitting continuous employment of personnel, in large measure preventing seasonal unemployment and part-time use of tools and machines. In these and in other ways it simplifies the problem of financing the business.

It reduces the number of specially trained workmen required, by reducing the number and variety of processes and operations.

It increases output of workers by making possible the application of specialized machinery and tools, and results in increased skill and speed of working due to repetitive processes.

It decreases the work of personnel in designing, drafting and other considerations of product, by permitting concentration of expert knowledge on a few highly developed lines.

General administration and management are decreased by making possible more complete and less expensive

advance planning and calculation in estimating, scheduling, ordering, recording, and cost accounting; and after manufacture, in conveying, distributing, and shipping of product, testing and inspection, bookkeeping, maintenance, repairs, and operation. It reduces the cost of all these because of there being fewer items to consider.

Standardized products can be sold more readily, as the purchaser is aware of their advantages, can make his selection more rapidly, and has confidence in their quality and performance.

**3. Better Serves the Consumer.**

Standardization protects the buyer, who ordinarily has no first-hand or expert knowledge of many of the things bought. Buyer and vendor are enabled to speak the same language, and such disagreements as occur can be settled by the interested technical experts without the necessity of resort to the courts. Standardization places competition upon the basis of essentials and eliminates minor and irrelevant variations, thus saving much time and expense on the part of both buyer and vendor.

Standardization simplifies the problem of buying, since standard products need not be described in detail, but may be referred to by a recognized name and a generally accepted capacity, size designation, or number.

**Various Aspects of Standardization.**

Standardization may be considered under several aspects:

1. Relations between Men, Methods, and Products.
2. Standardization of Nomenclature.
3. Standardization of Variety, or Simplification.
4. Standardization of Dimensions.
5. Standardization of Quality or Specifications.

These various aspects of standardization will be considered in succeeding chapters.

*The philosophy of industrial standardization* may be comprehended in the statement that standardization is not intended to be of advantage and use to an individual undertaking, alone, but to the economic structure of an entire people.

These advantages are particularly the conservation of *time*, *labor*, *material*, and *money*.

# CHAPTER V

## STANDARDIZATION

### PARTICULAR CONSIDERATIONS

#### 1. Relations between Men, Methods and Products

From a broad viewpoint, standardization may be considered in connection with *men*, *materials*, *methods*, *products*, and *uses*.

**The Human Element.**

Of all the elements involved in industry, the *human factor* is today one of the most serious problems confronting the business man. The individual remains to be studied, trained, developed, and brought up to the degree of maximum results already reached by products and processes, *but without any attempt at standardization*, as his individual initiative should be retained.

Standardization is a principle of the highest theoretical wisdom and greatest practical utility, when judiciously applied to industrial and commercial affairs, but is utterly pernicious and destructive when applied to the human mind and its activities. The standardization that is so good for machines and products is not good for the human mind because it is not a machine. It is an individuality, each mind unique and different from all others, in its needs and in its capabilities. The standardization of ideas and ideals, then, is more serious, because it is certainly true that if these were standardized, human beings would become as common clay bricks, indistinguishable one from another.

Psychology now teaches that human beings are *classifiable*, however, as to mental characteristics, that is, they may be grouped as far as suitability for certain industrial occupations is concerned.

No machine, broadly speaking, is so perfect that it can be used as a substitute for trained judgment. The finest mechanical device never acquires the ability to correct its own mistakes. It never learns. It gets use and wear, but no experience. Judgment, vision, imagination, courage, and experience have never yet been built into a machine. Until they are, there will be no substitute for the human mind.

The ability to get maximum results from materials and machines is relatively easy and common, but to get maximum results from men is much more difficult and rare. The answer probably is to be found in *applied psychology*. All business is ultimately the affair of minds; it starts from minds, it works through minds, it aims to serve minds. By industry, commerce, and transportation alike, the demands of minds are to be satisfied. Psychology is now taking its place beside physics and chemistry, and their application in engineering, as the aid of business and industry.

The era just closing has been a time of marvelous development in material forms of engineering. The era we are now entering will show equally great advances in the problems of a new branch of engineering known as *human engineering*, which is now rapidly being differentiated.

Human engineering may be defined as the science and art of selecting, training, and using men, or of planning, organizing, and operating groups of men.

**Materials.**

The raw materials used in the manufacture of a product must be of standard and uniform quality if the

process of manufacture is to be regular and the grade of the product is to be maintained.

Manufacturing is, in general, a process by which raw material has work done upon it, or in connection with it, and is thereby converted into a new class of articles technically termed finished stock. But the term *raw material* is a very elastic one. It must not be considered solely to mean material in a crude state. Pig iron or steel billets are raw material for one industry, but bolts, screws, stampings and castings of all kinds, angles and structural shapes, may be the raw material of others. Raw materials may even be quite complex devices, such as electric motors, switches, controllers, gears, and other mechanisms. *The raw material of an industry is simply the material as it enters that industry.* The finished product of one industry may thus be the raw material of another. It is seen that *raw* materials, as they are commonly called, *ripen* into finished commodities.

**Methods.**

A product made continuously from standard-grade material more readily permits standardization of each step in the process of manufacture than if the quality is of variable grade. This is attained by the adoption of the one best and most economical method of doing each thing as taught by plant and engineering experience, and making it standard practice.

**Product.**

A standardized product made to definite specifications permits an output to the maximum uniformity possible within the limits of manufacturing skill. A uniform product made and sold continuously permits a steady production schedule, a building up of stocks during periods of low demand, and their depletion during periods of high demand. Without a standardized basis, the

only alternative is to follow the *hand-to-mouth* method. The standardized product is manufactured to meet definite wide needs, according to precise specifications, and is constantly tested to ensure its conforming to standard grade.

For cheap production for use by the masses, sound industrial economy demands the elimination by the special or little-used product, and its substitution by the standard or most widely used and most efficiently produced goods.

In most branches of industry, standardization plays an important part. American industry is based upon quantity or mass production, and this, in turn, depends upon standardization. Quantity production means a large organization and investment, large output per machine, and a relatively small amount of manufacturing cost represented in each unit of the article. In quantity production, the units must be made exactly alike in design, and the process of manufacture must include certain tolerances to allow for wear in tools and high speed in production. All this makes for low cost—in fact, the natural law of machine production is: *The greater the output, the lower the cost per unit.*

There are limitations to the standardization of products. Wherever special, individual requirements have to be met, the factory-made article is out of place. Clothing, for example, is made in factories, but if we wish to obtain clothing that fit exactly, and not merely approximately, we go to the custom tailor, who does not carry standardization far. In fact, standardization is the antithesis of individuality. Individuality is the essence of art; to be beautiful and individual, it would seem that a thing must bear the impress of its maker's personality.

Three hundred years ago, Descartes, first of modern philosophers, wrote ". . . there is seldom so much

perfection in works composed of many separate parts, upon which many different hands have been employed, as in those completed by a single master."

**Uses.**

One type, grade, shape, or size of an article will not meet all the requirements of the consumer, neither is it desirable to have such an extensive variety that the differences are small and meaningless. The ideal condition is to have just enough variety to meet all the real needs with no overlapping.

The true significance of standardization is often overlooked. Efforts toward an extension of its principles are attacked, on the one hand by those who believe it menaces artistic expression, and on the other by those who see in its adoption a complete submergence of the individual.

Yet, as the far-reaching effects of sane standardization are more fully understood, not only is it clear that such fears are groundless, but, without a high degree of standardization, modern standards of living would be impossible.

### 2. Standardization of Nomenclature

One of the greatest business and industrial needs is the standardization of scientific and technical words, terms, phrases, definitions, abbreviations, symbols, diagrams, etc. Standardization of these elements of our technical language is fundamental in importance. It is very important that there be acceptable definitions of the terms used in specifications and contracts because it enables purchaser and producer to use and understand the same language. Some progress has been made in this field, but there is still a very wide diversity of usage.

Unfortunately, the language used in connection with science, industry, and business is not always consistent.

A limited store of expressions is compelled to accommodate itself to the ever-changing needs of the laboratory, shop, market place, and office. The context, or verbal explanation, supplies the clue to the precise meaning in view at the moment.

The need for the standardization of abbreviations is emphasized by the existing confusion resulting from the variety of symbols, for one thing, and the multiplicity of meanings of one symbol. The expression *pounds per square inch,* for instance, may be represented by at least a half-dozen abbreviations. Some English journals use *h.p.* for *high potential,* whereas, in the United States, it is generally used to mean *horsepower.* Whether or not the letters *h.p.* should be capitalized or hyphenated is not agreed. The mark ″ may mean inches, seconds, or a quotation. It is also used in mathematical work for distinguishing letters in the same group of quantities, as A′, A″, etc.

Great confusion necessarily occurs due to the use of two or more different symbols for the same thing. The economies which will be gained by eliminating these ambiguities will be very great both for the student and for the engineer who must refer to the varied literature of a technical subject. Standardization of engineering symbols and abbreviations should also eliminate the difficulty which foreign engineers have in correctly translating English articles into their own language, when they find widely divergent practices in the use of abbreviations.

The definitions of technical terms used in specifications and contracts and in general industrial transactions should be used in their correct sense. Many of the civil cases with which our courts deal hinge upon the exact meaning of words and phrases. As a matter of fact, a large part, perhaps the greater part, of standardization is essentially agreement on definitions.

Loose phrases in describing products, such as, "all materials shall be of the best commercial quality," and "good workmanship shall be furnished throughout," which are even yet frequently used in specifications and contracts, are but invitations to the law courts. In a wide range of products, such loose phrases are giving place to definite, clear-cut specifications, which may be interpreted in the acceptance or rejection of material without danger of misunderstanding by any competent engineer or testing laboratory.

*Grades* and *grading rules* are forms of specifications which enable buyer and vendor to speak the same language, thus eliminating disputes and litigation.

All nomenclature should be so definite that it will not be subject to individual interpretation. Interpretations differ and are likely to lead to misunderstandings, and if ambigous words, terms, phrases, etc. are in a specification or contract, a lawsuit may even be the result.

The Germans have made the interesting proposal that a *code word* be set up for every standardized article, permitting such items to be ordered by telegraph or radio, with a maximum of accuracy and a minimum of effort and expense. Such code words would also be of importance in advertising standardized articles to the consuming public, much like the practice during the World War, when highly standardized articles of military equipment became known under abbreviated names. This idea is not new, however, as the United States Navy Department now has a code word for each item, as well as code words for various phrases, in its Standard Stock Catalogue.

A similar *Federal Standard Stock Catalogue* is now in preparation which it is expected will soon be adopted by the United States Government, to govern all bureaus and offices of the government.

### 3. Standardization of Variety, or Simplification

Standardization of variety, or simplification, primarily involves the elimination of unnecessary *types, grades, shapes, and sizes* of manufactured articles; secondarily it involves business methods and practices.

The basic principle of *standardization of variety* is that a single item of product shall serve for as many different purposes or for as many different classes of equipment and kinds of construction as possible. It is a recognized fact that manufacturers' and retailers' store stocks are unduly inflated because of too many sizes and kinds of raw material and supplies, too many designs of car and locomotive parts performing the same function on different classes of equipment, and too little interchangeability between different makes of proprietary articles and devices. Many of these items, because of their special character, have become or will become inactive stock with the attendant danger of their eventually being scrapped without having given the intended service.

A study of this problem, through some agency so organized as to *coordinate* the efforts of manufacturers and users in determining what are the proper steps in sizes, the minimum requirements in kinds, and to what extent it is desirable or possible to obtain interchangeability in parts of mechanical equipment, such as cars and locomotives, machinery, and proprietary articles, would result in a material reduction of the number of items stocked.

Simplification of store stocks, by reducing the number of items, is productive of numerous economies, among which might be mentioned the following: More economical purchase due to the smaller number of items ordered, with consequent increase of quantity per item, eventual reduction of manufacturing costs, and elimination of

special articles which involve higher prices and longer delivery periods. Another result is more economy in accounting and the better control of stock, the cost of which is directly proportional to the number of items involved. Simplification is also productive of quicker turnover and smaller stock balances, because a single item of stock protects a greater number of requirements; less tendency to frozen stock with the attendant deterioration, obsolescence, and probability of eventual scrapping because of its special nature; less storehouse space and consequently more convenient and economical arrangement of stock; and, finally, less danger of the undesirable condition of repair work delayed due to lack of parts. Capital charges carried on unnecessarily large stocks makes standardization of variety of the greatest economic importance.

**Standardization of Variety by the War Industries Board.**

Standardization of variety, or simplification, was first made use of by the United States Government during the World War. This activity was known as the *Conservation Division of the War Industries Board*, and was charged with the responsibility of releasing the largest possible amounts of labor, capital, materials, and equipment for war purposes. The Conservation Division started functioning as part of the War Industries Board on May 8, 1918. It represented a continuation of the work of the *Commercial Economy Board*, transferred by the President under the Overman Act, from the Council of National Defense, where it had been in operation since its creation, Mar. 24, 1917. It had two courses open: (1) to curtail production in so-called non-essential industries; (2) to stop non-essential uses of labor, capital, materials, and equipment in all industries. The latter course was chosen.

The Conservation Division decided that, to carry out the purpose for which it was organized, it was necessary to:

1. Secure all feasible reductions in number of styles, grades, sizes, colors, finishes, etc., of the industry in question.
2. Eliminate styles and grades of articles which violated principles of economy in use of constituent materials.
3. Eliminate features of adornment which added nothing to usefulness of articles.
4. Reduce production and sale of such articles as were of lesser importance for comfort and satisfaction of the population.
5. Foster substitution of articles and materials which were plentiful for those which were scarce and difficult to produce.
6. Discourage use for unimportant purposes of articles which were needed for more important purposes.
7. Standardize sizes, lengths, widths, thicknesses, weights, gauges, etc., in such a way as to preserve sufficient strength and durability, but to effect economies in materials and labor.
8. Reduce waste of materials in manufacturing processes generally.
9. Secure economy in use of samples for selling purposes.
10. Secure economy in containers by eliminating smaller and unusual sizes.
11. Secure economy in packing by increasing number of units per package.
12. Secure economy in shipping space and packing materials by baling instead of boxing wherever practicable.

Through application of these restrictive measures, factories which dispensed with various multiplicities

of materials, processes, and products, which avoided excessive duplication of stocks, methods, and price ranges, found their productive capacities appreciably enlarged. By specializing on the remaining products, they operated with a degree of effectiveness previously unattained.

Much has been done in trade as a whole through the action of *Trade Associations* with the assistance, frequently, of the Fabricated Production Department of the *United States Chambers of Commerce.*

The Division of Simplified Practice of the Commercial Standards Group of the National Bureau of Standards, Department of Commerce, established in 1921, and amplified in 1927, is really a continuation and extension of the principles developed by the Conservation Division of the War Industries Board. It cooperates with producers, distributers, and consumers to eliminate needless variety in types, sizes, dimensions, and qualities, of commodities of common use.

Examples of the common commodities thus simplified in variety are as follows:

| Commodity | Original number of varieties | Number after simplification | Percentage reduction |
|---|---|---|---|
| Common brick | 44 | 1 | 98 |
| Paint brushes | 480 | 138 | 71 |
| Nails and tacks | 428 | 181 | 58 |
| Files and rasps | 1,351 | 496 | 63 |
| Shotgun shells | 4,076 | 1,758 | 57 |
| Metallic cartridges | 596 | 352 | 41 |
| Beds, mattresses, springs | 78 | 4 | 95 |
| Hotel chinaware | 700 | 160 | 77 |

The following business documents have been reduced to *one standard form each:* warehouse receipts; stock and

delivery forms; invoice, inquiry and purchase orders; bank checks, notes, deposit slips, notices, etc.

**Preferred Numbers in Simplification.**

An interesting application of standardization of variety is the so-called theory of *preferred numbers*, which is based upon the reasoning that the human mind naturally prefers a *geometrical progression* to an *arithmetrical progression* in fixing a series of grades sizes. Preferred numbers have been given a great deal of attention by standardizing authorities in Germany and France, but has not come into extended use in this country.

**Unlimited Variety Expensive for Consumers.**

Experience has clearly demonstrated that there are many practices in American industry which cost the ultimate consumers, in the aggregate, enormous sums without enriching the producers. These are often due to competitive demands, real or assumed. Many salesmen, in order to satisfy the whims of particular customers, will insist upon the manufacture of new styles or new grades of articles, requiring increased expense to the manufacturers and increased expense to both wholesalers and retailers in carrying more lines of stock; these, in turn, causing increased expense in maintaining salesmen and providing them with samples as well as in advertising. The consumer, the general public, is no better served by the satisfaction of these unreasonable demands, but *the consumer ultimately pays the bill.*

In the simplification of industrial effort, the fundamental difference between *design* and *style* must be determined. Style is the disguising of the design to appeal to the individual, whereas design responds more to the mass desire. Design is intended to meet the needs of utility; style is intended to meet the desires of temperament. Both design and style, in any specific

article, originate from the initial demand or expression of a need or desire for that article.

Thousands of articles of present-day use had their origin in a certain dissatisfaction with things as they were. Next came a desire for some relief; this desire became a want, and finally a need, with resultant ways and means to satisfy that need. Through evolution and education, the breaking down of customs, traditions, and habits, the public has accepted the design. Once that has been accomplished then comes the process of variation—the play of the individual mind on the original design—until out of that variation has come certain accepted models, patterns, types, or styles.

Logically, then, if the user is to be able to differentiate between design and style, he must be educated to recognize in any given thing that which is *utility* and that which is *art*. Design is the intention or purpose as revealed or inferred from the adaptation of means to an end. Style is the mode of presentation, or the conformity to a recognized or *conventional* standard, that standard being determined more from the form, shape, appearance, pattern, color, or workmanship than from consideration of the fundamental purpose for which the thing is produced.

Standardization of variety, or simplification, is fundamentally an *economic movement*—a very real means of eliminating some of the avoidable waste in industry and trade. It is frequently based on *commercial expediency* rather than on *scientific fact;* technical research and engineering experimentation may or may not be necessary. This statement is not meant to imply that simplification is a *hit-or-miss* procedure or arrived at through *grab-bag* methods. Quite the contrary is true. Simplification is developed from the best practice and judgment of an industry or individual establishment. Facts are vitally necessary, but production and sales

records coupled with a true picture of the consumers' needs are usually sufficient for constructive simplification action.

A distinction is sometimes made between *standardization* of technical processes and their products, and economic selection, or *simplification* of variety of products and methods of procedure, but the latter is generally considered to be merely one aspect of the former, and the aims of both are identical; that is, *the elimination of waste* caused by the unnecessary multiplicity of procedures, processes, and products and the resulting complications of manufacturing and business methods.

Standardization is generally applied to some *individual article* or some *particular process,* while simplification is commonly considered in connection with *lines of products* or *methods of business procedure.* Simplification, or the elimination of excess types, grades, sizes, finishes, etc., of products, or superfluous or unnecessary methods, certainly results in standard products or practices. In other words, simplification is standardization by *elimination,* rather than by *selection.* In either case, the result is the establishment of a *standard.*

The term simplification, frequently is more appealing than standardization of variety, as it sounds less formal.

### 4. Standardization of Dimensions

Standards of size or form are those which establish particular dimensions, or combinations of dimensions, for the construction or working of machines and equipment or their components. The dimensions standardized are usually chosen as being suited to the best degree to meet the requirements of existing structures, equipment, apparatus, machines, tools, or parts, by providing for *intermembering, interworking,* or *interchangeability* of parts and supplies.

A more highly developed form of this type of standard is seen in what may be called the *standard component,* a specialized machine part or device which may be used in more than one assembly.

In dimensional standardization, in cases where accuracy is a factor, some statement of tolerances or allowances is usually necessary in order to give the dimensions practical and definite significance. Systems of *tolerances* and *allowances* are a form of dimensional standardization underlying in a fundamental way whole classes of ordinary dimensional standards.

Dimensional standards may also be chosen as combining in a single instrument, device, or practice, needed characteristics of suitability, convenience, capacity, economy, and strength for a given purpose or a group of purposes having common factors.

Interchangeability in manufacturing, which is of the greatest importance in mass production, depends upon proper shop standards, gauges, threads, and patterns. Gauges are particularly important in modern manufacturing in which metallic parts are involved. Economical quantity production requires accurate gauging to insure proper duplication and interchangeability, otherwise hand fitting would be required in assembling, which would be costly. The proper use of gauges insures this interchangeability. The adoption of limit gauges is one of the greatest advances industry has made.

Under modern production methods, every part must be made exactly right or it is worthless. There is no time to fit and adjust parts that are even slightly out of the way in size. Every part must conform to specific dimensions before it gets to the assembly line. This calls for machine work of extreme accuracy which is accomplished largely through the use of precision machining and jigs and fixtures that insure precise

workmanship, but this machinery must be adjusted correctly and constantly checked, and every part measured and gauged as it is produced. Many gauges and master gauges are used in this system of production. The modern precision grinding machine has made possible the finest dimensional workmanship.

The decade 1910 to 1920 saw a noteworthy development in instruments for precise measurements, which has made possible the production of interchangeable parts in commercial quantities. Without means of accurate gauging, the mass production of automobiles, firearms, typewriters sewing machines, and hundreds of other things made and used daily in great numbers would be impossible. Gauges are precision tools, and are now used very largely in industry.

For example, in the production of the *Lincoln automobile*, the Ford Motor Company claims that the manufacturing is held to the closest limits of accuracy known to the automotive industry. The inspection tolerances observed are remarkable; there are more than 5,000 operations in which the deviation from standard is not permitted to exceed one one-thousandth of an inch and more than 1,200 operations in which it is not permitted to exceed one-half of one-thousandth. In more than 300 operations, the camshaft and crankshaft, for example, the tolerances are held to one-quarter of one-thousandth. In the case of steel balls for ball bearings, the limit of tolerance is set at one-ten-thousandth of an inch (0.000,1 inch)!

In such refined mechanical work, precision instruments are necessary to attain the results required, and precision gauge blocks are the industrial *standard-of-standards* used. Special jigs and fixtures are used and these are checked with gauges, of which there are many thousand in use, all controlled by the reference gauge blocks.

Inspection in such work is carried to the *n*th degree. The crankshaft, for example, is subjected to 66 different inspections; the camshaft to 30 different inspections; the cylinder-block casting is given three separate borings and is then ground within a tolerance of one one-thousandth of an inch in diameter, and one-quarter of one-thousandth for parallelism, and it is given 30 different inspections before it is finished. Cylinder walls are *honed* in a special machine to provide the finish demanded.

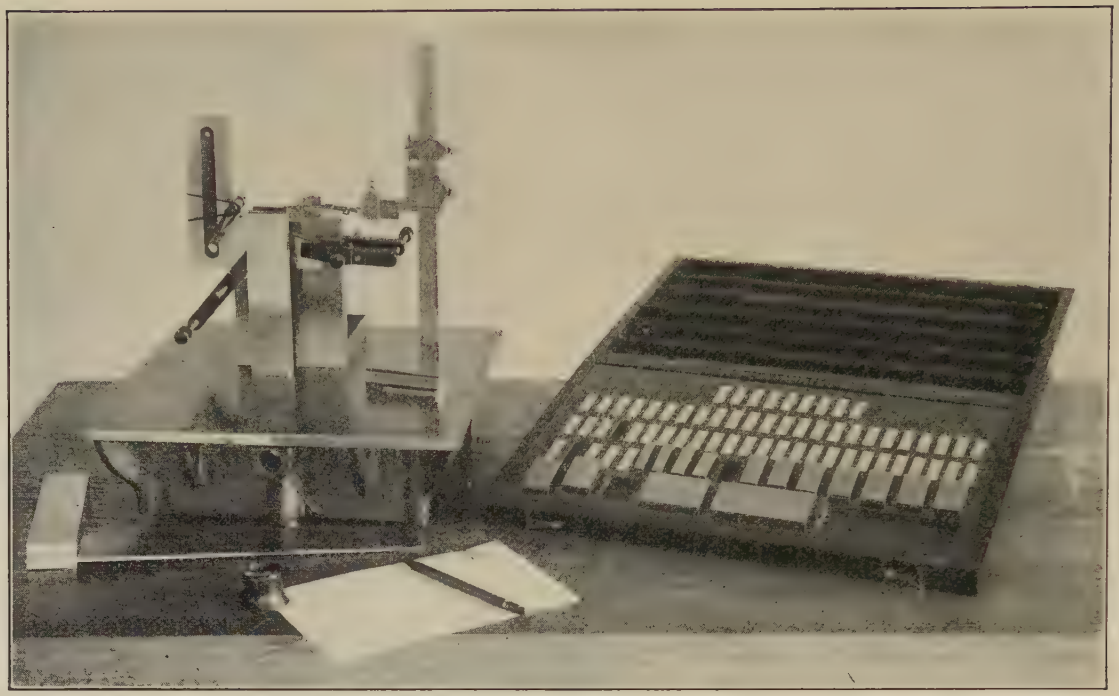
Gauge blocks (Fig. 11), are now made of almost unbelievable fineness of workmanship. They are made of heat-treated steel which has been seasoned to practically eliminate warping or "growing." The block faces are flat and parallel to within 0.000,01 inch or less, and the parallel surfaces are distant from each other to within 0.000,01 inch or less, of the absolute dimension marked on the block. The blocks are accurate to within one-hundred-thousandth of an inch *per inch* of dimension.

Several American companies are regularly manufacturing precision gauge blocks which are guaranteed to be within 0.000,01 of the dimension stamped on them; special sets are being made which are accurate to 0.000,-002 inch *per inch*.

As an example of what can be done, a set of these blocks, accurate to within one-millionth part of 1 inch (0.000,000,1 inch) was made by Johansson, of the Ford Motor Company, the originator of gauge blocks.

It is believed that the surfaces of these blocks more nearly approach the perfect theoretical plane than any other produced by the hand of man, with the exception of optical "flats," which are discs of clear, fused quartz, with surfaces departing less than 0.01 of a wave length of light from true planes.

These surfaces possess extraordinary qualities when rubbed across the palm of the hand and brought in



*(Photograph furnished by courtesy of the National Bureau of Standards)*

FIG. 11.—Precision gauge blocks used as reference end standards in precise mechanical work. The extensive use of these precision gauge blocks is necessitated by the small tolerances allowed in the manufacture of interchangeable machine parts.

The errors of these gages seldom amount to 0.5 micron (0.000,02 inch)—in most cases to not more than 0.25 micron (0.000,01 inch).

contact with one another, holding together with a force equivalent to 33 atmospheres. Scientists have offered various theories in explanation of this phenomenon—atmospheric pressure, molecular attraction, and surface tension of the minute film of oil on the contact surfaces. Possibly it is a combination of all three. Two blocks wiped across the skin and pressed or "wrung" together with a slight sliding movement have resisted a direct pull of 210 pounds, which proves that there is something besides air pressure alone that makes them adhere.

Another company which specializes on fine measurements has made reference scales which are accurate to 0.000,001 of an inch. The measuring machines used by this company give definite indications to the hundred-thousandth of an inch, and these reference scales, read through a microscope, are used in setting the machines so that continous accuracy is assured. Pure science is thus applied to making and testing gauges, making master screws, and ruling linear scales unsurpassed in point of accuracy. The master screws and the best gauges and linear scales are true to within 0.000,000,1 inch.

The American system of *interchangeable manufacture* has been put on a sound basis of exact measurement through the assistance of exact science. The research work of the physicist has made possible such great accuracy in industrial operations.

**Standardization in Manufacturing.**

The standardization of component parts is at once more productive of economy and less hostile to progress than that of complex structures. The same standard structural-steel sections are used with advantage in thousands of different sorts of structures for use on land and sea, while the same standard screws are used for hundreds of thousands of different purposes.

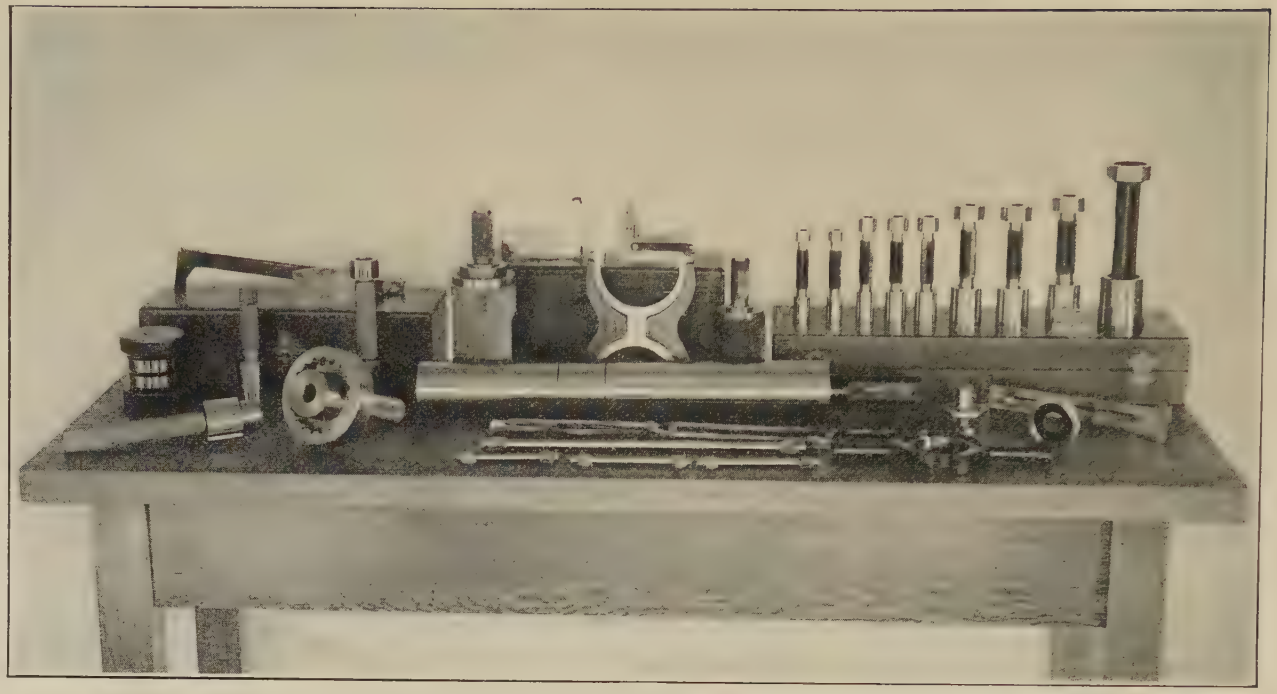
Standardization usually attains the highest perfection in the case of a product which has been long in use, and of which both the component parts and the general design have been subjected to long and varied trial, for in such a case the total experience of a multitude of users exceeds the finest imagination of a few users having constructive genius.

On rare occasions, there may be an imperative need for sudden mass production, which allows no time for protracted experience. An instructive instance of this kind occurred when the United States had unexpected occasion to provide a large supply of airplanes, trucks, rifles, etc., on models, which the experiences of the World War had developed. Several eminent American engineers "pooled" their knowledge in order to devise a general plan for the economical and rapid production of airplane engines. They proposed to build the engines in various models, each using the same standard cylinders, pistons, valves, camshafts, and so on. Thus the parts of wrecked eight-cylinder or twelve-cylinder engines would be interchangeable, and a new engine could be assembled from the parts of wrecked machines. European aeronautical engineers assisted in forming the plan, but it was decided not to adopt any European model of engine, because British and French machines, as a rule, are not adapted to American manufacturing methods. They are highly specialized, requiring much handwork from mechanics who are almost artists. Therefore, exact mechanical standardization was applied in American fashion to do as much of the fine work as was possible. But it was found that some finishing work had to be done by hand at the last in almost every case. Since, however, cylinders, pistons, and every other part of the motor had been standardized, they could be produced rapidly and economically by a great many factories operating under government contracts. They could also be rapidly

assembled, either by any of these plants or at a central assembly plant.

In a similar manner, rifles were required in large numbers, and, therefore, quantity production and standardization were imperative. Standardization was regarded as an essential for two reasons, one of them a matter of practical tactics in the field and the other relating to production speed. To begin with, the soldier on the battlefield is his own rifle repairman. His unit usually has on hand a supply of weapons damaged or out of commission for one reason or another. If, therefore, any part of the soldier's rifle is broken or damaged, he can go to the stock of unused guns on hand and take from another rifle the part which he requires; and it will fit his gun, *provided* there has been standardization in the manufacture of the rifle. But if the guns have not been standardized and each weapon is a filing and tinkering job in the assembly room of the factory, then the soldier in the field is not likely to be able to find a part that will fit his gun; and his rifle, if damaged, goes out of commission. Or, if he finds a part which fits but does not fit perfectly, his gun may not function properly and he himself may suffer serious injury. Standardization is also essential to great speed in production. If one plant producing rifles encounters a shortage of any of the parts of the gun, it can send to another plant and secure a supply of these parts, a favorable condition in manufacture that is impossible if the weapon has not been standardized.

The production and inspection of the Springfield Army rifle requires the use of 1,263 gauges, and a machine gun about 2,200 gauges. The Ordnance Department of the Army has under its charge in the various arsenals more than 500,000 gauges (Fig. 12), the replacement value of which is about $30,000,000.



(*Photograph furnished by courtesy of the National Bureau of Standards*)

FIG. 12.—Types of munition gauges.

The gauge types shown above illustrate a few of the kinds of gauges used in the mass production of materials. The particular gauges illustrated are for munition production.

The standardization of ammunition likewise requires that the various parts of each component be made to fit each other properly and perfectly. Gauging has to be resorted to frequently in the process of manufacture to make certain that there is perfect interchangeability of parts of each component to prevent any waste of time in selecting parts to fit each other. This extreme accuracy makes necessary a large number of gauges, which have to be designed at the same time as, and in coordination with, the design of the component. For example, in a complete round of artillery ammunition, 80 dimensions must be gauged. To standardize the gauges used for these 80 dimensions, 180 master gauges are required, while the actual number of different gauges used during the various stages of manufacture of a complete round is over 500. Government inspectors require over 200 gauges in their work of inspecting and gauging the finished components for the shell, so in all about 800 gauges are used in the process of manufacturing a complete round of artillery ammunition, to insure interchangeability and proper functioning of parts.

A short time ago, 19 German manufacturers and one Swedish manufacturer built 700 locomotives for Russia, all of identical design. Every part in every one of them was made interchangeable with the corresponding parts in all the others. These locomotives can, therefore, be transferred to any part of the railroad system with the assurance that standard stock repair parts can be used. This will mean a tremendous economy, not only in original purchase, but in store expense and operation.

### Standardization—Bane or Blessing?

To many people *standardization* has a most forbidding sound and there is a not uncommon conception of standardization as a process that will reduce everything to a drab monotony. When standardization has done its

perfect work, it is said, we shall all wear the same kind of clothes, eat the same kind of food, live in the same kind of houses, and think the same kind of thoughts, and our critics assure us the world will be a stupid place!

The other side of the picture is more encouraging. Standardization does not attempt to select and set up the one supreme best standard. It selects, instead, many that are good, and its judgment is not final but tentative and ever open to revision, when justified by changes in the arts of manufacture or the requirements of the user. Changes should not be made, however, until justified from all points of view, and the proposed changes should be as carefully considered as were the original standards.

In standardization work, there must be a definite objective. In the words of Seneca, the Roman philosopher, "If a man does not know to what port he is steering, no wind is favorable." Furthermore, in standardization work, it is necessary to exercise judgment and discrimination. Standards can be carried to an absurd limit, as in "The Scarlet Empire," by David Parry, where inspectors forced each person to laugh every 20 minutes for the good of his health. As in the case of many other good things, *standardization can be overdone.* We are forced from the facts, however, to conclude that there can never be any real danger from misdirected standardization.

A business or industry exists for a definite purpose, which is realized by the proper interplay of *money, men, materials, machines, methods,* and *management.* In all of this interplay, the all-important element is *time,* since the fundamental principle involved in mass production is the rapid, systematic, routine production of units alike in as many characteristics as is possible.

The foremost industrial engineers now agree that the most important element in an industry or business is

primarily not materials or energy, but *time*. Everything in the business world in the final analysis amounts to a matter of time. Never before has it been so true that *time is money. Speed! Speed! Ever more speed!*

Modern business and industrial managers systematically and efficiently utilize both human and mechanical energy in all of their operations, and follow the counsel of the poet Goethe to economize time—it passes quickly!

## CHAPTER VI

## STANDARDIZATION OF QUALITY

### SPECIFICATIONS

Standardization of quality is of especial importance from the standpoint of the *purchaser* and *user* of commodities, inasmuch as the best and most economical way to get desired quality is by the use of adequate *specifications*. The term *quality* as applied to commodities, and as defined by specifications, means those characteristics which distinguish goods.

Twenty years ago, very little attention was paid to specifications in purchasing; commodities were purchased only on general classifications, as the consumer was somewhat familiar with the properties of the relatively small number of articles that he used.[1] Since that time the enormous development of industry has caused a corresponding increase in the number of types, qualities, sizes, etc., of commodities, which have been produced to meet modern desires or needs, and greater demands are being made upon materials and products than ever before. Industry is constantly calling for *lower prices* and *greater efficiency* of material, equipment, and supplies, and this involves commodities of superior properties, or lower costs, or both.

In order to be able to guarantee the performance of equipment, *manufacturers* have been obliged to specify definitely the characteristics of the materials used. The need for a more exact statement of the requirements and, in many cases, improvement in quality, has been recog-

[1] For further details on purchasing see: N. F. Harriman, "Principles of Scientific Purchasing," McGraw-Hill Book Company, Inc., New York.

nized. The most effective means of accomplishing these results is the *standardization of specifications.*

In embarking upon a consistent program of standardization of quality, the first problem is the selection from among the enormous number of items purchased, of those for which standardization and specifications shall first be attempted. Obviously, those items involving the largest amounts of money and which are of the greatest importance in the operation of the business should first be standardized. These items range from machinery, completed products, semi-fabricated products, and materials, down to office supplies. The next step consists in drafting a tentative specification, in conference with representatives of the departments by which the articles in question are to be used; manufacturers should also be consulted. The friendly clash of opinions between manufacturers and users of goods is very often most enlightening to anyone concerned in the development of standard specifications.

**Object of Specifications.**

The object of a purchase specification is to inform the vendor in regard to what the purchaser wants, and what he does not want, and, as far as may be, to make *wants* correspond to *needs.* Often the purchaser does not know definitely what he wants; and what he says he wants is not what he should have for his needs. To this state of affairs is due the great variety of inadequate, capricious, and arbitrary specifications for various articles which are a thorn in the flesh of the conscientious vendor.

Sometimes purchasing agents and others are persuaded by overzealous or uninformed salesmen to write specifications in terms that restrict the available supply to the extent that only a small number of manufacturers can comply with the specification. This is far worse than

buying directly by brand name, since the vendors are led to believe that competition is possible. The practice should be carefully scrutinized before it is adopted, as the resulting restricted competition will not insure the best price being obtained.

The *tailor-made specification* should especially be avoided as far as possible, in setting up standards for general use, or use over a wide range of service conditions.

When perfected, the specification becomes a true standard of quality for a given use. It fixes in measurable terms the magnitudes of the qualities or properties pertinent to a given serviceability of products. The specification is the common meeting ground of the maker, dealer, and user. It is the point where science is applied to the quality of the service or the measurement of such quality. The true specification embodies at once the users' needs and the makers' ability to produce. As such, to the extent that it is effective, it becomes a controlling technical factor in regulating the processes of industry. Its position is, therefore, of supreme importance.

The general principle applicable to all qualities is that no quality can be described without comparing it to some *standard*. The fact that quality is a variable leads to one of the most important conceptions of what constitutes quality. Quality is different for each separate item of the class under consideration, and this fact of variability must be clearly understood and considered when standards of quality are being set.

Quality, in the sense here used, is *that which fits a product for a given use*. A product is not simply *good*, it is good for a certain purpose, and the word *quality* is meaningless apart from the use in view. Good quality means good for a definite use. The ordinary purchaser or user frequently is not an expert on quality of products, and in many cases the quality can be lowered and he will

be none the wiser until the article is put into service. Business is facilitated and the causes for disputes between purchaser and vendor are avoided if purchases are made on the basis of specified definite qualities, understood by both purchaser and vendor.

### Specifications *versus* Brands, Trade Names, Standard Samples, Etc.

The quality of commodities is the sum of a number of related characteristics, such as *shape, dimension, composition, strength, workmanship, finish, color, adjustment,* etc. Some of these characteristics are measurable and capable of numerical expression, while others are not. The descriptions of the dominating qualities should be definite, so that it will be understood just what the product is intended to be.

For those characteristics which are not capable of adequate expression, it is usual to say that the shipment shall be equal to a given *standard sample.* Precautions, of course, must be taken to see that the sample itself does not materially change (all standard samples do change more or less in one or more characteristics in the course of time), and thereby gradually deviate from the standard originally set.

The use of standard samples is probably the best that can be done, until the qualities concerned can be reduced to a basis of numerical expression.

Brand specification describes the practice of buying by specifying a *brand, trade mark,* or *trade name.* Brand specifications are so easily confused with standardization and standard specifications that it is not at first apparent that they are really diametrically opposed.

There is a difference between the *branding of a product* and what advertising men call *brand specifications.* Branding is merely a means of making it possible to identify the product of a certain maker, and when used

on products manufactured to standard specifications, makes it possible for the buyer to identify the products that are claimed to conform to standard specifications. But when branding is used primarily to make it possible for a manufacturer to create a *brand specification* through national advertising, it serves fundamentally to enable the manufacturer to evade or lessen price competition. Users should buy according to established *standards* (specifications) in order to make production subservient to consumption.

The tendency of modern purchasing is undoubtedly toward the use of complete specifications, and away from the use of the terms *equal to standard sample*, or according to *brand, trade mark, trade name, catalogue reference*, etc. The words *equal to*, or any corresponding terms, should never be used in a specification, except as being *descriptive*, and catalogue references should be used in a *descriptive and not in a restrictive sense*. Purchasing on sample at best is a makeshift of the poorest sort. It is true that certain qualities cannot be described adequately in words, but in such cases the reference to the standard sample should be limited to those qualities which cannot be described adequately.

There are many products for which existing methods of test are not adequate to determine the essential characteristics. When a product that falls in this class is to be bought, the subject is discussed with the vendor, describing the application and such properties as are known to be requisites. A sample is obtained when practicable and given a laboratory test. A small trial order is then followed through the shop and the performance of the product is determined in the application for which it is intended. If satisfactory results are obtained, the product is approved, and the vendor is notified to furnish the same quality on future orders. Finally a specification is prepared including such

properties and test methods as are applicable, and purchases are limited to such vendors as have furnished satisfactory trial orders.

In some cases, orders may be confined to approved vendors for certain products difficult to manufacture, which it is desirable to obtain only from vendors who are known to be able to furnish them, even though the specification gives an adequate description. In all of these cases, limited specifications may be used to advantage, in that they allow shipments to be partly checked even though all of the requirements are not given.

The same general procedure is followed in preparing a complete specification as in the case of the limited specification. Unless it is known that a product of certain properties will be suitable, a trial shipment is obtained before issuing the specification and allowing orders to be placed in the routine manner.

**Use of an Acceptable List of Approved Commodities in Purchasing.**

Some large purchasers have an *Acceptable List of Approved Commodities* to facilitate purchase of satisfactory materials, equipment, and supplies, under the following circumstances:

1. When the time duration of a complete test to determine suitability is such as to cause too great delay in delivery or too great expense of inspection of products, *e.g.*, dry cells, insulating material, lubricating oil, etc., whether or not detail specifications are available, or:

2. When the necessary tests to determine suitability are such as to require the use of apparatus or testing equipment of a complicated or expensive nature which is not in common industrial use, or:

3. When technical requirements cannot be fully covered by specifications, *e.g.*, several brands or even types of material, equipment, or supplies, all differing

in essential details, may be satisfactory for a given purpose. In such a case, a complete specification which would fully protect the purchaser's interests could not be drawn without unduly limiting competition, or:

4. When the product is of an experimental nature, or in a rapidly developing stage, *e.g.*, radio material.

When material or apparatus has been found to be in all respects satisfactory, the name of the manufacturer together with the trade name, type, or symbol of the apparatus or material is placed on the Acceptable List of Approved Commodities and proposals of all low bidders are considered, if they state that they intend to furnish apparatus or material under the same trade name, type, or symbol, and the same in all respects in quality and suitability for use, as the apparatus or material on the test of which approval was based.

When bids are received, award is made to the lowest bidder offering a product appearing on the Acceptable List of Approved Commodities. All proposals of bidders who do not appear upon the Acceptable List of Approved Commodities, and whose bids are lower than those of bidders who are on the Acceptable List, are rejected unless it appears to be to the advantage of the purchaser to take other action.

**Commodities Should Be Tested for Compliance with Specifications.**

It should be clearly stated in the invitation for bids that the inspector will select samples for such tests as are ordinarily made on the product for brand approval and will send them to a designated laboratory, where the samples must satisfactorily pass the specified tests, before acceptance of the product for shipment from the works of the contractor. The cost of the test should be borne by the purchaser or by the bidders, as circumstances warrant, but in either case the cost

of all samples and shipping charges should be borne by the contractor.

In the inspection of products from an Acceptable List for which no formal specifications have been prepared, or when definite inspection instructions are not outlined in the contract, the following procedure should be followed:

1. Inspection to be made for quality, dimensions, and workmanship.

2. In lieu of tests, a guarantee may be accepted from the contractor stating that "Product submitted for inspection is equal to the sample submitted to the (name of laboratory) under test No. (give laboratory test No.) approved by . . . , in letter of (date)."

**Desirability of Purchasing on Performance.**

Both the producer and the consumer are interested primarily in the *performance* of the material in service. The emphasis should, therefore, be placed upon the performance rather than upon the composition, physical properties, construction, or method of manufacture. This is the object of the *work values* and *utility factors* introduced into specifications as performance requirements.

The producer should be given the greatest possible latitude in furnishing a product for the purpose desired. Where details of composition and manufacture are prescribed, the producer is limited in range of product. He may be prevented from developing a product differing from that specified, but giving superior, or at least as good, performance at perhaps a lower price. In many cases it is not practicable to specify performance, and it is necessary to specify certain characteristics or to describe the construction, but this should not be done when it can be avoided.

It should be noted that standardization of materials and products does not necessarily influence quality.

Standardization and quality are frequently confused in use, but they are not synonymous. Quality is a *characteristic*, whereas standardization is a *process or procedure.*

That *quality* is fundamental has been conclusively demonstrated. Test one by one the elements of satisfaction, and it will be found that prices and terms lose half their appeal if they are not backed up by quality. What is to be gained by promptness in the matter of delivery or of low price, if the products upon receipt have to be rejected because of deficiency in quality?

A suitable specification is one which enables bidders to know exactly what is desired or required and what procedure the purchaser will follow to satisfy himself that the specification has been complied with. Defective and incomplete specifications, whether due to compromise of quality for temporary economy, or through lack of data, should be replaced by those in which the best magnitude of each property involved is so specified as to predetermine the definite quality best meeting the need.

The suitability of an article for the service required is very important, otherwise money would be wasted in the purchase of products of a quality better than needed, and economic losses would result from the use of cheap but low-grade products. The great value and business importance of specification standardization, from the standpoint of a large purchaser, lies in consolidated purchases to a single standard specification for a given article. This results in *economy.*

The development of specifications, especially specifications which are to be used as a basis for competitive bidding, is a problem of no small difficulty. The difficulty is to make them sufficiently precise and detailed to secure all the advantages that flow from precision and definiteness without at the same time making them so voluminous and intricate as to discourage and hinder competition.

Standard specifications frequently must be made to conform to recognized trade specifications, as the cost of *special fabrication* would be excessive. In setting standards for commodities, it is ordinarily wise and economical to choose between articles that are commercial and readily secured, unless very large quantities are required, and the conditions of use extraordinary.

Large organizations now have a central authority for the development of specifications. This is the case with the United States Government. Many large industries and railroad systems have an engineer of standards, or a standards committee. This is the case with the New York Central Lines, Pennsylvania System, Union Pacific System, Southern Pacific Company, General Motors Corporation, Ford Motor Company, Western Electric Company, and United States Steel Corporation. In other cases this is combined with the chief purchasing function. Where this is done, there invariably results a marked standardization in the articles used in the several branches of the service.

Standardized specifications are now recognized by purchasing officers as the proper basis for efficiency in purchasing, for they tend to secure for all similar needs the articles which experience has shown to be the best for the purpose. By reducing the number of items to be purchased, they simplify the work of the purchasing office. They simplify the work of inspection by reducing the variety of items on which inspectors must exercise their judgment, and the work of accounting and of auditing is lessened similarly. The head of the central purchasing department is in the best possible position to see the obvious desirability of standardization from a business standpoint.

A full and precise specification greatly enhances the *trading reputation* of the purchaser for exact knowledge of his needs. It informs the dealer that shiftiness during

the course of a purchase agreement is not a part of the purchaser's policy—a certainty which, obviously, encourages competition among the most desirable vendors and secures the lowest prices. Examination of the best modern practice in purchasing leads to the conclusion that specifications should be written in detailed and complete terms with reference to every possible controversial point; in short, *individual preferences* of users of goods and partiality of inspectors should be reduced to a minimum. In fact, the purchase of materials and products in accordance with well-defined specifications, understood and agreed upon by the producer and consumer and enforced by the latter, is the only way by which they can be purchased successfully by competitive bids.

The fundamental requirements for efficient purchasing have been stated as:

1. Specifying the right product.
2. Buying the product desired on the best terms as to price and delivery.
3. Insuring that the product received is as specified.

The use of complete or standard specifications will assist materially in carrying out these three requirements. By the term *specification,* as used above, is meant a description of the product used as the basis of purchase, giving the requirements in sufficient detail to insure the delivery of products of the desired characteristics.

The specification is a statement of the user's needs and what the manufacturer is required to supply. The specification should include limiting values for the properties and dimensions necessary to meet the required service, with proper tolerances.

In the usual manner of formulating purchase specifications, a base line of quality or performance is established, below which products will not be accepted, and above

which no allowance will be made in price, in evaluating bids.

The only requirements for successful and economical purchasing on specification are care in setting the requirements of the specification and care in the inspection to insure getting what was contracted for.

A specification which can not be *checked* or *verified* with the product actually delivered is worthless. In fact, it is worse than no specification at all, for it paves the way for continual deceit and dispute between buyer and vendor.

Purchasing on specifications is not particularly popular with vendors who have in their regular selling price the cost of establishing their trade name or trade mark.

One of the most difficult riddles of purchasing is the continual quarrel between quality and price. This situation can be cleared only by proper and adequate specifications. Purchasing by bids based on well-formulated specifications really sets an upper and lower limit to the quality. The too-good is eliminated in the price comparison of bids; the too-poor is rejected by the minimum quality specified. The result is that the deliveries are of that quality above and below which lies waste. *Net utility per dollar expended* is the criterion at which level this good-enough quality range should be set.

There are many reasons which should emphasize the desirability of basing purchases on properly standardized specifications. Lack of standards of quality for use in purchasing is *unbusiness-like and costly.* This can be corrected by purchasing on proper specifications, followed up by adequate testing and inspection.

In all standardization work there are two main factors to be considered, namely, what the standards should be, and how to make them effective. A specification of any kind is written to be enforced and it is of

value only to the extent to which its provisions are enforced by fair and uniform inspection. Unless enforced, it is valueless and becomes a dead letter. Its fair enforcement is a benefit alike to the honest purchaser and vendor and a stumbling block to those on either side who desire to resort to subterfuge or deception. Furthermore, it must be enforced uniformly at all times to be effective.

It is a basic principle of purchasing that *competition reacts to the benefit of the purchaser*. If competition is to be secured and maintained there must be a clear definition of standards so that bids may be made intelligently. The purchase of materials and products in accordance with well-defined standards, understood and agreed upon by the purchaser and producer alike in the contract, is the only way by which they can successfully be purchased by competitive bids. With such standards, a purchaser is enabled to take advantage of this method in securing the lowest price that can be obtained for an article of the required standard. Without them, the reputable bidder is not only at the mercy of the unscrupulous one, but the purchaser is deprived of the legitimate economy resulting from this method of purchasing.

It is obvious, with the keen competion of business and the insistence of purchasers on obtaining the lowest price, that some of the goods offered to the general purchaser will be below the standards set by the specification. Inspection tends to keep products up to the specified standard and the consumer profits thereby. There is always the possibility that, through error, goods rejected by large consumers may be shipped to small consumers who do not inspect material purchased.

There are doubtless many manufacturers who generally are strict in their own inspection, but, probably, even most of these use their own judgment as to the necessity

of some of the stricter limits mentioned in standard specifications, and if it were not so, goods would cost more to the general consumer. Yet it ought to be possible for a consumer to buy small quantities of nearly any kind of material or article that is covered by standard specifications, with the certainty that the goods fulfilled the specifications.

**The Writing of Specifications is a Progressive Art.**

The writing of specifications is not a task that can be performed at any one time and be considered completed. A specification that reflects the best practice today may be found to be inadequate a year later. Satisfactory specifications are the result of growth and they must change, from time to time, to harmonize with the changes in both the art of manufacture and the requirements of the user's service; they can develop only as the area of definite knowledge expands. Looking at the question from this viewpoint, the importance and necessity of continuous study in the formulation of standard specifications is at once apparent.

In the use of specifications, provision should be made for their revision. The sequence of events in connection with their application, use, and revision, is as follows: *original draft of specification, proposal, bids, order or contract, delivery, inspection and test, acceptance or rejection, storage, issue, observation in service, and data for revision.* This natural history of a specification thus comprises the entire cycle of events from the specification itself to the reports of service fed back for later revision.

**Requirements of a Specification.**

In addition to specifying the properties of the product desired, methods of sampling to insure representative samples and methods of testing should be included. The values obtained for the properties mentioned are usually

largely affected by the test methods employed. When, however, test methods have been established as standard practice in an industry, it becomes unnecessary to describe them in specifications. Any necessary instructions as to inspection should be given for guidance, for both the inspector and the producer. The specification also should give any desired instructions for packing and marking, and the procedure to be followed in connection with rejection of defective material.

Experience has proved that a *Standard Specification Form* is a matter of considerable importance. The form adopted by the Federal Specifications Board is based on the form which has been used successfully for many years by the two departments of the Federal Government which are the largest purchasers of commodities, both in amount and variety. This Standard Form is described, and illustrated with a sample specification prepared in conformity with it, in the Appendix. This sample specification is also an example of a specification written on the basis of a *work value* or *utility factor*.

This form is not necessarily inflexible; yet the experience of these two Federal departments and the Federal Specifications Board is that despite the fact that existing specifications cover many hundreds of commodities of the most diverse characteristics, a departure from the Standard Form is seldom necessary.

The advantages of a standard form in a large establishment dealing repeatedly with thousands of materials, supplies, and equipment, and having a large permanent purchasing and inspecting force in both laboratory and field, is apparent. These advantages may not obtain to any comparable extent in an organization whose purchases are more restricted both in volume and variety. In any organization using purchase specifications, however, a standard form will be found to be helpful to the specification writer. By putting down, first of all,

the numbered sections with their titles, he will find that, after a little experience, details will more readily fall into their proper places and in their logical sequence. With these headings to guide him, the chance of omitting some important point is reduced; the specification will be more concise, and the labor of revising, when revision is necessary, will be lessened. A specification written in conformity with a standard form is also more convenient in use, as similar requirements always appear in the same part of the specification.

A specification should always be dated, and should bear a numerical symbol which is capable of extension when the specification is revised. Federal specifications bear an arbitrary number, such as "10"; when revisions become necessary, it is issued under a new date and given a new number; 10*a* for the first revision, 10*b* for the second revision, etc.

**The Preparation of Specifications.**

In the preparation of specifications, the first step is to decide upon the properties of the product necessary to meet the desired service condition, and the method of determining these properties. Care should be taken not to make the specification too cumbersome by adding unnecessary requirements. The specification, as written, should be submitted for comment to the designing engineer responsible for the application of the product, to the department or the shop where it will be used, and to the inspection department. It should then be forwarded to the producer for criticism. The comments from these various sources are considered, the preliminary draft is modified, if necessary, and the final specification is issued.

In submitting proposed specifications, or revisions of existing specifications, to the industry concerned, for comment and criticism, it will be found to be very

advantageous and to facilitate the work, if criticisms are requested through the central trade organization concerned. For example, comments on specification for rubber products should be requested through the Rubber Association of America. A government publication listing all of these organizations, under the title "Commercial and Industrial Organizations of the United States," is available, by purchase, from the Superintendent of Documents, Washington.

It is important that a new specification be submitted to the producer for his comments before it is issued. The producer can tell whether he can produce the article to meet the specification, and if not, what he can furnish. He can also give valuable suggestions for minor changes that will not interfere with the use of the product and will allow commercial products to be furnished instead of special grades.

Owing to the lack of knowledge of the properties of many products when they are first used, and also to the undeveloped state of the art as regards methods of test for many products, a considerable proportion of specifications for products are incomplete in some respects. A specification which reflected the best practice at the time it was written may be inadequate after a few years due to improvements in the art of manufacture or to the development of a new product having more desirable properties than those called for.

It is usually undesirable to include in a specification, requirements which cannot be checked by the purchaser, but there may be cases where such statements are of value in giving the producer a better idea of the products desired.

It is sometimes claimed that the use of specifications increases prices. While there may sometimes be a tendency toward higher prices, particularly when the producer is not familiar with the specification, in general,

a quality specification, by permitting competitive bidding, tends to lower prices rather than to raise them. The cost of preparing specifications and of inspecting products is more than offset by the savings effected by the better quality and greater uniformity of the products, and by the more effective use made possible through greater knowledge. In many cases, the expense entailed in a few shipments of defective products would amount to as much as the cost of specifications and inspection for a long period of time.

Under certain conditions, the use of specifications in purchasing products is not practicable. Various *commercial* grades of products may be sufficiently uniform in quality always to be suitable for certain uses where the requirements are easily met and it would therefore not be necessary to buy on specification. In many such cases the reason for the uniform quality will be found to be previous standardization of the raw materials and the adoption of standard specification by the producers. In general, however, specifications are desirable for use in purchasing. The benefits to be derived from their use are fully recognized and appreciated both by producers and consumers.

## CONCLUSIONS IN REGARD TO THE FORMULATION OF SPECIFICATIONS

1. A specification for a product should contain the *fewest possible restrictions*, consistent with obtaining the material desired.

2. The *service* which the product is to perform, in connection with reasonably feasible possibilities in its manufacture, should determine the *limitations* of a specification.

3. All parties whose interests are affected by a specification should have a voice in its preparation.

4. The one who finally puts the wording of the specification into shape, should avoid making it a place to show how much he knows, as well as a mental attitude of *favor* or *antagonism* to any of the parties affected by it.

5. Excessively severe limitations in a specification are suicidal. They lead to constant demands for concessions, which must be made if the work is to be kept going, or to more or less successful efforts at evasion. Better a few moderate requirements rigidly enforced, than a mass of excessive limitations, which are difficult of enforcement, and which lead to constant friction and sometimes to deception.

6. There is no real reason why a specification should not contain limitations derived from any source of knowledge. If the limitations shown by physical test are sufficient to define the necessary qualities of the material, and this test is simplest and most easily made, the specifications may reasonably be confined to this. If a chemical analysis or a microscopic examination, or a statement of the method of manufacture, or information from all four, or even other sources, are found useful or valuable in defining limitations, or in deciding upon the quality of product furnished, there is no legitimate reason why such information should not appear in the specifications. Neither the producer nor the consumer has a right to arrogate to himself the exclusive right to use information from any source.

7. Proprietary articles and commercial products made by processes under the control of the manufacturer cannot, from the nature of the case, be made the subject of specifications. The very idea of a specification involves the existence of a mass of common knowledge in regard to any product, which knowledge is more or less available to both producer and consumer. If the manufacturer or producer has opportunities, which are not available to the consumer, of knowing how the varia-

tion of certain constituents in his product will affect that product during manufacture, so also does the consumer, if he is philosophic and is a student, have opportunities not available to the producer, of knowing how the same variation of constituents in the product will affect that product in service, and it is only by the two working together, and combining the special knowledge which each has, that a really valuable specification can be made.

8. A complete workable specification should contain the information needed by all those who must necessarily use it in obtaining the product desired. On a railroad, for example, this may involve the purchasing agent, the manufacturer, the inspector, the engineer of tests, the chemist, and those who use the product. A general specification may be limited to describing the properties of the product, the method of sampling, the amount covered by one sample, and such descriptions of the tests as will prevent doubt or ambiguity.

9. Where methods of testing, analysis, or inspection are well known and understood, it is sufficient if the specification simply refers to them. Where new or unusual tests are required, or where different well-known methods give different results, it is essential to embody, in the specification, sufficient description to prevent doubt or ambiguity.

10. The sample for test representing a shipment of a product should always be taken *at random* by a representative of the consumer.

11. The amount of product represented by one sample can best be decided by the nature of the product, its importance, and its probable uniformity, as affected by its method of manufacture. No universal rule can be given.

12. The purchaser has a right to assume that every bit of the product making up a shipment meets the require-

ments of the specification, since that is what he contracted for and expects to pay for. It should make very little difference, therefore, what part of the shipment the sample comes from, or how it is taken. Average samples made up of a number of samples are only excusable when the limits of the specification are so narrow that they do not cover the ordinary irregularities of good practice in manufacture.

13. Retests of a product that has once failed should only be asked for under extraordinary conditions, and should be granted even more rarely than they are asked for, errors in the tests, of course, excepted.

14. Simple fairness requires than when it is desired that a product once fairly rejected should nevertheless be used, some concession in price should be made.

15. Where commercial transactions are between honorable people, there is no real necessity for marking rejected products, to prevent its being offered a second time. If it has failed once, it will probably fail a second time, and if return freight is rigidly collected on returned shipments, the risk of loss is greater than most vendors will care to incur. Moreover, it is so easy for the consumer to put an inconspicuous private mark on rejected products that it is believed few will care to incur the probable loss of business that will result from the detection of an effort to dispose of a rejected shipment by offering it a second time. Rejected products should not be mutilated by the inspector, as they are the property of the vendor.

16. All specifications in actual practical daily use need *revision* from time to time, as new information is obtained, due to progress in knowledge, changes in methods of manufacture, and changes in the use of products. A new specification, that is, one for an product which has hitherto been bought on the reputation of the makers and without any examination as to

quality, will be fortunate if it does not require revision in from 6 to 10 months after it is first issued.

17. In the enforcement of specifications, it is undoubtedly a breach of contract legitimately leading to a rejection if the specified tests give results not wholly within the limits, and this is especially true if the limits are reasonably wide. But it must be remembered that no tests give the *absolute truth*, and where the results are near, but just outside, the limit, the product may actually be all right. It seems better, therefore, to allow a small margin from the actual published limit equal to the probable limit of error in the method of testing employed, and allow for this margin in the original limits, when the specifications are drawn.

18. Many producers object to specifications on the ground that they are annoying and harassing, and really serve no good purpose; the complaint is just in the cases of many unwisely drawn specifications. But it should be remembered that a good, reasonable specification, carefully worked out, as the result of the combined effort of both producer and consumer, and which is rigidly enforced, is the best possible protection which the honest manufacturer can have against unfair competition.

19. Many consumers fear the effect of specifications on prices. Experience indicates that after a specification has passed what may be called the experimental stage and is working smoothly, prices show a strong tendency to drop below figures prevailing before the specifications were issued.

20. A complete workable specification for a product represents a very high order of work. It should combine within itself the harmonized antagonistic interests of both the *producer* and the *consumer*, it should have the fewest possible requirements consistent with securing a *satisfactory* product, should be so comprehensive as to leave no chance for ambiguity or doubt, and above all,

should embody within itself the results of the latest and best studies of the properties of the article which it covers.

### Precepts for Specification Writers

1. Either *specify* or *omit*. Eliminate all clauses that reflect indecision or lack of knowledge. Do not put anything in the specifications that will not be enforced to the letter.

2. Use simple words. Use technical words in their *exact* technical meaning. Do not use words that are subject to ambiguous interpretation.

3. Use nouns. Do not use pronouns. It is better to repeat the nouns, even at the sacrifice of elegance.

4. Do not write long and involved sentences.

5. Use commas sparingly. Do not construct sentences in such form that the omission, addition, or misplacement of a comma will alter the sense.

6. Make the language a clear and concise expression of just what is meant.

7. Give directions, not suggestions. Tell the manufacturer *definitely* what shall or shall not be done.

8. Do not attempt to conceal obligations or to place all the risks on the manufacturer.

9. Either specify *results desired* and leave methods and properties to the manufacturer, or specify *methods* and *properties* desired and assume the responsibility of results.

### Advantages of Using Specifications.

Some of the advantages to be gained by the use of standardized specifications are:

#### 1. Reduction in the Number of Items of Materials and Supplies Used.

When no standards are in use, there gradually develops a large number of materials and supplies of the same

general properties, but differing in minor details and requiring separate manufacture. This constitutes a large *economic waste*. Standardization, by concentrating attention on one standard product of a kind, permits production in larger quantities at lower cost. Better facilities for manufacture, inspection and testing can be provided, thus increasing the output and improving the quality and uniformity of the material. Smaller investment in the manufacturing equipment and lower stocks of raw materials and finished products are the result. The better quality and greater uniformity of standard products may allow less expensive products to be used with a saving in cost.

**2. Interpretation of Requirements.**

Purchase specifications have the important function of giving all of the interested persons the same understanding of the requirements to be met. The purchasing agent uses a specification to serve as complete information to accompany a purchase order. He thus avoids the practice so often followed of giving a brief incomplete statement with an order which may be misunderstood and which also may be different for each order. The producer receives sufficient information for the manufacture. The inspector uses it as a guide in his inspection to determine the properties required and also the detailed methods of sampling and testing that are given, avoiding either too lax or too stringent inspection. The designer learns from it what properties he may expect in the product, aiding him in making the best application of materials in his designs. Without such a common source of information, misunderstandings are very likely to occur, and products may be furnished which are not best adapted for the purpose desired.

**3. Test Methods.**

Standard methods of *sampling* and *testing* enable both producer and consumer to test the product in the same way and obtain comparative results. The values determined for the properties of the products depend largely upon the manner of sampling and testing.

**4. Competitive Bids.**

By the use of specifications, the consumer obtains bids on the *same quality* of product from all producers. When there is no specification, both quality and price quoted are likely to vary widely so that the purchaser is unable to make an intelligent comparison. Specifications are, therefore, a protection to the reputable manufacturer, who otherwise might be in competition with manufacturers of inferior products without the differences in quality being apparent.

**5. Knowledge of Materials.**

More complete and accurate information is available regarding the properties of products bought on standard specifications. This is of much value to the designer, as well as the user, enabling both to apply the product more effectively.

**6. Production.**

Production is stabilized, as there is a steadier demand for standard than for special products. Standardization also allows manufacture for *stock* during periods of business depression. This keeps the plant running, thus reducing the labor turnover and keeping down overhead expense.

**7. Sales.**

Sales of products are facilitated as established standards become widely known and their merits are recognized.

**8. Deliveries.**

Better deliveries may be obtained by the consumer, as standard products are usually more available than special products. In many cases they are carried in stock by the producer. *Quicker deliveries warrant lower investment in stocks.*

## CHAPTER VII

### NATIONAL STANDARDIZING BODIES

There are twenty countries in which national standardizing bodies have been established, as follows, with the dates established:

Austria (1920), Australia (1922), Belgium (1919), Canada (1919), Czechoslovakia (1922), Denmark (1924), Finland (1924), France (1918, reorganized in 1926), Germany (1917), Great Britain (1901), Holland (1916), Hungary (1921), Italy (1921), Japan (1921), Norway (1923), Poland (1924), Russia (1923), Sweden (1922), Switzerland (1918), and the United States (1918).

All of these bodies, with the exception of the British Engineering Standards Association, were, therefore, established during or since the World War.

The procedure of all the national bodies is based largely upon the method of cooperation developed by the British, which has come to be technically known as *Sectional Committee* procedure. The actual formulation of specifications and other forms of industrial standards and the technical decisions involved are in the hands of sectional committees, each of which is made up primarily of accredited representatives of the various bodies concerned with the standard in question.

As a matter of principle, the national bodies generally do not initiate work, but wait for an expression of a desire on the part of the interest concerned that a certain project shall be taken up. Draft standards worked out by the sectional committees are published for criticism in technical and trade papers before being finally approved.

In several countries a special journal is issued by the national body.

In the work of the American Engineering Standards Committee, the sectional committee is designed to be a true cross-section of all the industrial groups concerned with the standardization work for which it is responsible. The various interests concerned (producers, distributors, and consumers, including public authorities and independent experts) cooperate in the work.

The American Engineering Standards Committee is the most decentralized of all the national bodies. One of the participating bodies of each sectional committee is designated as *sponsor;* this body organizes the sectional committee and is responsible for its effective functioning. No other body has the sponsorship arrangement, though the German standardizing body has something similar to it in parts of its work.

The national standardizing bodies which are of the greatest interest in the United States, on account of the extent of their work, are *The American Engineering Standards Committee, The British Engineering Standards Association*, and the *Deutscher Normenausschuss* (The German Standards Committee).

### AMERICAN ENGINEERING STANDARDS COMMITTEE

In recognition of the need for some method to prevent duplication in standardization work and promulgation of conflicting standards, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Society for Testing Materials appointed a special joint committee to formulate a method of cooperation in formulating standards. This committee held its first meeting on Jan. 17, 1917. The result of this and subsequent meetings was the organization of the American

Engineering Standards Committee, made up initially of representatives of these five societies. In 1918, the United States Government War, Navy and Commerce Departments designated representatives, and, in 1919, the constitution was broadened to permit the representation of other national bodies.

Organized as the national clearing house for engineering and industrial standardization, the committee serves as the agency through which standardization by associations, societies, and governmental agencies is passing to the stage of standardization on a broadly national scale.

The committee now acts as the official channel of cooperation in international standardization and provides an information service on foreign engineering and industrial standardization matters, except those in connection with the International Electrotechnical Commission and the International Commission on Illumination. It maintains headquarters in the Engineering Societies Building, 29 West Thirty-ninth Street, New York, N. Y.

The *American Engineering Standards Committee* (A. E.S.C.) itself, usually referred to as the *main committee*, is primarily an administrative and policy-forming body (Fig. 13). It does not concern itself with the technical details of a standard offered for approval, but considers the procedure followed in the formulation of the standard, the adequacy of the representation of the various interests concerned on the sectional committee organized by the sponsor body to formulate the standard, and the action by which the standard has been adopted by the sectional committee and approved by the sponsor.

The sectional committee is made up of representatives officially designated by the various bodies interested in the particular standardization project in hand. In order to provide for well-balanced sectional committees,

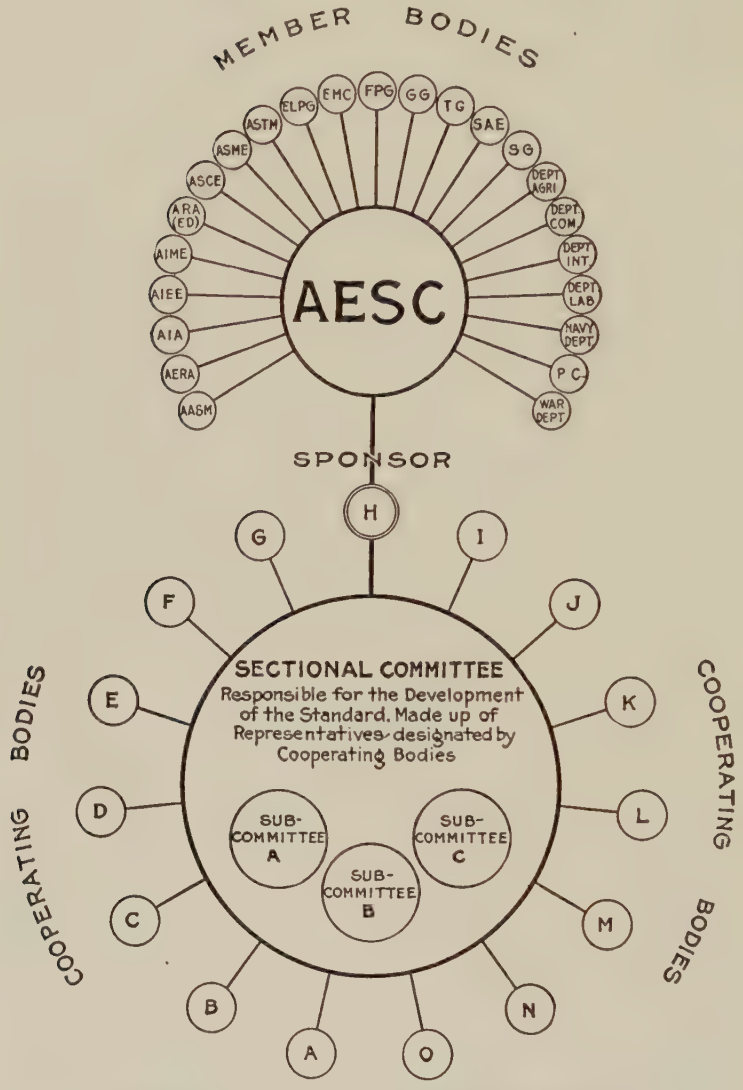



FIG. 13.—Organization of the American Engineering Standard Committee.

the individual members are classified according to their principal business affiliations. In the case of most projects, a classification of the interests concerned into producers, consumers, distributers, and general interests has been found sufficient. In the matter of *safety codes*, the conditions are more involved, and it is usually necessary to provide for the representation of six distinct groups. The American Engineering Standards Committee assures itself that the personnel and composition of each sectional committee are authoritative and adequately representative of the various interests concerned in the standard or group of standards for the formulation of which the sectional committee is responsible.

Approval of a standard by the American Engineering Standards Committee means, not that the main committee has itself worked over and passed upon the technical details of the standard, but that it has satisfied itself that all organizations concerned have had an opportunity to participate in the work, that the work has been carried out under a procedure that has been regular, open, and aboveboard, and that the standard represents a real national consensus on what is best in American engineering and industrial practice. An existing standard may be approved by the American Engineering Standards Committee if it has been developed substantially in accordance with American Engineering Standards Committee rules of procedure, or has by actual practice proved its right to become a standard.

Work upon a standardization project is undertaken by the American Engineering Standards Committee only upon a formal request from a responsible body, and then only after the committee has assured itself that it is the desire of industry that the work shall go forward. A formal conference or a special committee of representatives of the bodies concerned with the

proposed project is asked to decide: (1) whether the work shall be undertaken; (2) if so, what its scope shall be; (3) how the work shall be organized; and (4) how it is to be related to any other work having an important bearing on it.

*Advisory committees* have been organized to suggest subjects for *standardization* and determine the desirability of standardization in several lines of industry, recommend *sponsors*, define and limit the scope of projects, adjust conflicts, clear up ambiguities, follow up and expedite work in progress in the development of standards, and report from time to time upon progress within their fields of activities. Two such committees are now functioning, the Mining Standardization Correlating Committee and the Safety-code Correlating Committee, and a similar committee in the electrical field has been organized as the result of formal proposals made by the American Institute of Electrical Engineers and the Electrical Manufacturers' Council. A similar step has been taken for the mechanical field by the American Society of Mechanical Engineers.

When the development of a proposed standard seems desirable, the American Engineering Standards Committee designates a sponsor or joint sponsors for the work. The sponsor organizes the *sectional committee*, is responsible for seeing that the work is continuously prosecuted, and provides for the publication of the standard. The relation of sponsor to the other cooperating bodies officially represented on the sectional committee is somewhat similar to the relation of the chairman to the other members of a committee. The American Engineering Standards Committee will not approve the recommendations of any sectional committee without the previous approval of the sponsor or joint sponsors to which the sectional committee makes its report.

Six executive departments of the Federal Government—Agriculture, Commerce, Interior, Labor, Navy, and War—and one independent establishment, The Panama Canal, are represented on the American Engineering Standards Committee. Thirty-three branches of the Government are officially represented on sectional committees. The National Bureau of Standards is acting as sole or joint sponsor for thirteen projects, the Bureau of Mines for seven, the Forest Service for two, and the Public Health Service for one. The Department of Labor designates representatives of labor on all sectional committees dealing with safety codes, and is publishing approved safety codes as government documents. The state governments are taking a leading part in the entire safety-code program through the Association of Governmental Labor Officials and the International Association of Industrial Accident Boards and Commissions. State highway and traffic commissions are participating in American Engineering Standards Committee activities through the American Association of State Highway Officials, the regional conferences of motor-traffic administrators, and the railway and utility commissions.

Prior to the official promulgation of specifications for engineering materials by the *Federal Specifications Board*, the proposed specifications and their proposed revisions are submitted informally to the American Engineering Standards Committee, with a request for their assistance in obtaining criticism from national associations and societies and from industry.

In order to avoid overlap or duplication in undertakings, the American Engineering Standards Committee and the Division of Simplified Practice of the Commercial Standards Group of the Bureau of Standards, Department of Commerce, are so conducting their programs that problems that can be handled by a consideration of

production data alone are referred to the Commercial Standards Group of the Bureau of Standards, whereas problems in the nature of standardization which involve technical considerations are referred to the American Engineering Standards Committee.

The American Engineering Standards Committee is cooperating actively with the national standardizing bodies in other countries. These bodies keep in active touch with each other by correspondence, exchange information in regard to new projects, draft standards, and compare general tendencies in the national work in the respective countries.

Complete sets of standards approved by the foreign national standardizing bodies and a large number of the standards issued by the important organizations in this country are kept on file at the headquarters of the American Engineering Standards Committee, which maintains an information service for the benefit of committees working under its auspices, of members and sustaining members, and of American industry generally. The American Engineering Standards Committee acts as a central distributing agent for the standards and specifications of the national technical societies and trade associations listed in the National Directory of Commodity Specifications published by the Bureau of Standards. It issues monthly a mimeographed bulletin for the benefit of sustaining members, giving information concerning activities in foreign standardization work and reviewing proposed and approved American standards and other developments in the American standardization field.

Under the auspices of the American Engineering Standards Committee, 91 standardization projects have been carried forward to completion and 150 additional projects are in various stages of progress.

Participating in the work through officially accredited representatives are 365 national organizations, technical, industrial, and governmental. Of these, over 170 are trade associations. Subscribing directly to its support are 267 organizations and firms interested in its work and listed as sustaining members.

The main committee is composed of official representatives of member bodies, of which there are now 24, comprising 35 separate national organizations, including 9 national engineering societies, 19 national industrial associations, and 7 departments of the Federal Government. These are as follows:

American Electric Railway Association.

American Institute of Architects.

American Institute of Electrical Engineers.

American Institute of Mining and Metallurgical Engineers.

American Mining Congress.

American Railway Association (engineering division).

American Society of Civil Engineers.

American Society of Mechanical Engineers.

American Society for Testing Materials.

Association of American Steel Manufacturers.

Electric Light and Power Group (Association of Edison Illuminating Companies, National Electric Light Association).

Fire Protection Group (Associated Factory Mutual Fire Insurance Companies, National Board of Fire Underwriters, National Fire Protection Association, Underwriters' Laboratories).

Gas Group (American Gas Association, Compressed Gas Manufacturers' Association, International Acetylene Association).

National Electrical Manufacturers Association.

Safety Group (National Bureau of Casualty and Surety Underwriters, National Safety Council).

Society of Automotive Engineers.

Telephone Group (Bell Telephone System, United States Independent Telephone Association).

United States Departments of Agriculture, Commerce, Interior, Labor, Navy, War, and The Panama Canal.

Nineteen other organizations, although not member bodies of the American Engineering Standards Committee, are serving as sponsors for standardization projects under American Engineering Standards Committee auspices.

The question of reorganization of the American Engineering Standards Committee, to make its scope of activities less restricted than is indicated by its present name, is now (1928) under consideration.

### BRITISH ENGINEERING STANDARDS ASSOCIATION

The *British Engineering Standards Association* was formed in 1901 under the title *Engineering Standards Committee* by the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institute of Naval Architects, and the Iron and Steel Institute. Shortly after this, the Institution of Electrical Engineers joined in the movement. The organization was incorporated as the British Engineering Standards Association under license of the Board of Trade in 1918 (Fig. 14).

The sole executive authority of the Association is vested in a main committee, consisting of 30 members, 21 of whom are nominated by the five institutions mentioned above, together with the Institution of Automobile Engineers; five (including one to represent the Federation of British Industries) are chosen by joint action of the nominated members, and three are nominated by Government Departments. Of these three, one represents the Board of Trade, another the Department of Scientific and Industrial Research, and the third is the Director of the National Physical Laboratory.

The Association exists for the benefit of British industry for the purpose of drawing up British standard

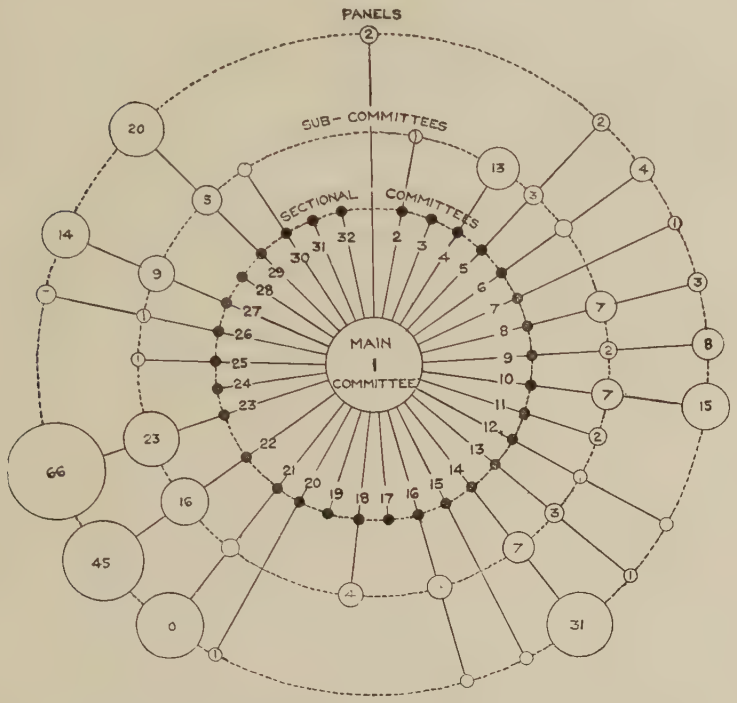



Fig. 14.—Organization of the British Engineering Standards Association.

Index to Sectional Committees

2. Finance. 3. Publications. 4. Overseas. 5. Ships tests. 6. Bridges, etc. 7. Railway underframes. 8. Locomotives. 9. Rails. 10. Machine parts. 11. Pipe flanges. 12. Cement. 13. Road materials. 14. Automobiles, motor cycles, cycles. 15. Vitrified ware pipes. 16. Cast iron pipes. 17. Rope pulley grooves. 18. Wire ropes. 19. Galvanized iron sheets. 20. Notched bar tests. 21. Ship and machinery details. 22. Electrical. 23. Aircraft. 24. Co-ordination of steel specifications. 25. Chemical fire extinguishers. 26. Limit gauges. 27. Non-ferrous alloys. 28. Pipe threads. 29. Chemical engineering. 30. Ball and roller bearings. 31. Fire hose couplings. 32. Sand-lime bricks.

specifications for materials, machinery, and apparatus for the engineering and allied industries, its object being, through standardization, to eliminate national waste,

to facilitate production, to simplify purchasing, and to help British industry meet competition in the world's markets.

The Association has become the accepted tribunal for the settlement of all the difficult questions, both technical and industrial, which arise in carrying out standardization of national scope in the industries which it covers. The Association does not embark on such work on its own initiative but waits for the initiative from some outside body, such as a representative trade organization, a technical society, or a government department. It has, however, no government control, its only authority being public opinion in the engineering and allied industries. Before appointing a committee to study any subject, the main committee assures itself by a representative conference of all interests concerned that there is a consensus of opinion favorable to the proposed work being undertaken and that it is to fill a recognized want.

From its inception, certain definite principles have governed the work of the British Engineering Standards Association, among which may be placed in the forefront the community of interest of producer and consumer, who are brought into consultation at the very commencement of any work; this, in fact, is the cornerstone of the movement. The Association is, in effect, a national organization in the closest touch with industrial requirements and modern technical knowledge.

For the purpose of the consultations and discussions leading to the issue of a new standard specification, the manufacturers concerned act, as a rule, through their trade organization. Consultation with the users or consumers is more difficult as usually they are not organized in the same way as manufacturers, but all practicable steps are taken to ascertain and take into account their views.

The British *standard specifications* are intended to include the technical provisions necessary for the supply of the particular material or apparatus concerned, but do not purport to include all the necessary provisions of a contract. They are of various types, sometimes specifying dimensions only where interchangeability alone is required, sometimes specifying quality of materials as well as dimensions, and at other times specifying only standards of performance to give an equitable basis of comparison. There are also standard methods of testing, and standards for terms, definitions, graphical symbols and markings, etc.

The subjects dealt with by the Association are arranged under the following sections:

1. Aircraft.
2. Automobile.
3. Chemical engineering.
4. Civil engineering (including road and building materials).
5. Colliery requisites.
6. Electrical.
7. Mechanical.
8. Metallurgical.
9. Petroleum products.
10. Ships' materials and fittings.
11. Transport.

The Association includes within its organization the British National Committee of the International Electrotechnical Commission (I.E.C.).

There are some 420 committees, subcommittees, and panel-committees, many of them standing committees, representative of different branches of industry, engaged in the work of the Association; and over 2,000 engineers and business men throughout the country give their time and experience to this work without fee or recompense. The large purchasing departments of the govern-

ment, which in many cases have rendered signal service, nominate technical officers to serve on most of these committees. In certain cases, these purchasing departments of the government have asked the British Engineering Standards Association to cooperate with them in drawing up specifications for the use of the departments. Such specifications are issued by the departments when, for various reasons, they cannot be issued by the Association as national standards. Over 200 British standard specifications and reports have been issued by the Association, and, in the majority of cases, have been widely adopted in Great Britain. They have also formed the basis of much of the work of standardization in the British Dominions. In addition to these, some 250 specifications for aircraft materials have been issued by the Association on behalf of the Air Ministry. Nearly 60,000 copies of British standard specifications were sold during 1925, and 20,200 distributed for the Air Ministry.

The Association is not a profit-making concern, and its only expenses are staff salaries, office expenses, and printing, which amount to about $80,000 a year. Under present arrangements, the Association receives an annual grant of $600 from the British Government, and $2,500 each from the Government of India and the Crown Agents for the Colonies. It also receives certain payments from government departments for services rendered. The great bulk of its income, however, is derived from donations and subscriptions, with a smaller amount from the sales of it publications. The subscriptions come mainly from trade organizations, which have considerably increased in number during the past 10 to 15 years and many of which have taken up the question of standardization and simplification.

Local committees have been established in the following British Dominions: *Australia*, *South Africa*, *New Zealand*, *Canada*, and *India*.

In Australia the *Australian Commonwealth Engineering Standards Association* was founded in 1922 by the Commonwealth Institute of Science and Industry, the Australian Institution of Engineers, the Australian Institute of Mining and Metallurgy, and the Australian Chemical Institute. It has a main committee composed of representatives of these institutions, of the State Governments, and of the Australian Associated Chambers of Commerce, Associated Chambers of Manufacturers, and Bureau of Steel Manufacturers, and appoints sectional committees as required. The main committee has decided, as a general policy, that where reasonably practicable, British Engineering Standard Specifications should be adopted, and the regulations prescribe that at the first meeting of a sectional committee, the Chairman shall bring under the consideration of members any existing British Standard Specification which covers the material or equipment to be standardized.

Agreement with or departure from British standard specifications is carefully indicated in the specifications issued. Where the specifications adopted are in complete agreement with the British specifications, they are issued, with the consent of the British body, as *Australian Standards.*

In South Africa there is the *British Engineering Standards Association* (*South Africa branch*) working on similar lines, and with the Departments of Mines, Public Works, Railways and Harbors, Posts and Telegraphs, and Navigation represented upon its committee. Some few standard specifications have been issued for matters with which the British Engineering Standards Association has not itself dealt, but generally the South African authority adopts the British specifications. Any proposed British specification is communicated to the South African body, and there is generally time for

criticisms to be received and considered before the proposed specification is finally issued.

In New Zealand there was formed some time ago the *British Engineering Standards Association New Zealand Local Committee*, which was intended to be in the same relation to the British body as the South African committee, but it does not appear to have been so active.

In Canada there is the *Canadian Engineering Standards Association*, with which the British Standards Association is in communication. Further, under a Canadian Act passed in 1924, the Canadian Research Association was empowered to establish a Canadian Physical Laboratory similar to the National Physical Laboratory, with the added power of issuing specifications and standardizing not merely instruments, but also the products of industry. In view of the economic community of interest between Canada and the United States and the opportunities of intellectual and personal contact between the Canadian Engineering Standards Association and the National Bureau of Standards in Washington, it is to be expected that the standards adopted by Canada should conform rather to those of the United States than to those of Great Britain; and it is understood that the standard specifications issued by the Canadian Engineering Standards Association tend, as a rule, to be in substantial agreement with those adopted in the United States.

In India the standardizing body is the *Institution of Engineers (India)*, which has quite generally adopted British Engineering Standards Association specifications. The India Railway Board has, it is understood, recently set up a conference of officials to consider railway specifications, but this body is believed to be dealing at present only with possible revision of the standardization of locomotives. The government of India has made considerable use of the British Engineering Standards

Association, and makes an annual contribution to its funds.

### DEUTSCHER NORMENAUSSCHUSS (DNA)

(German Standards Committee)

The original central standardization organization of Germany—*Normenausschuss der Deutschen Industrie* (N DI)—was organized in 1917 by the *Verein deutscher Ingenieure*. The work really grew out of the efforts of the government to increase production and to conserve resources during the World War. It soon became evident that the task was too great for a single organization, and other technical societies and industrial associations joined with the *Verein deutscher Ingenieure* in the support and development of the movement.

The German body, which originally started its work on purely industrial subjects, having expanded its activities outside this field, has, for this reason, quite recently changed its name from *Normenausschuss der Deutschen Industrie* (Standards Committee of German Industry) to *Deutscher Normenausschuss* (German Standards Committee). It is the national headquarters in Germany for technical standardization.

The German industrial standards bear the mark *DIN*, *Deutsche Industrie Normen* (German Industrial Standards). Inasmuch as the scope of work of the *Deutscher Normenausschuss* is now much greater than that of the original body which was designated *Normenausschuss der Deutschen Industrie*, the above mark is now interpreted to mean *Das Ist Norm* (That is standard).

#### Organization and Procedure.

There are a considerable number of participating engineering societies, industrial associations, and government ministries, and in addition there are 5,000 firms which are cooperating members. The main committee

meets infrequently, most of the detailed work being done by a smaller executive committee (Fig. 15).

The central office of the organization has ample quarters in the building of the *Verein deutscher Ingenieure*, in Berlin, and has a staff of more than 60 persons. The office provides an extensive information service on standardization work in Germany and other countries, which is available to the industry as well as to their working committees. This has been a most important factor in building up the work and in securing support for it.

Proposals for new subjects for standardization must come from some responsible body. The industry concerned is consulted, generally, by a conference of the various organizations interested to determine whether it is the consensus of opinion of the industry that the work should go forward. In case it is decided that the work is to go forward, the conference designates the chairman of the working committee. The working committee is made up of representatives of the interested organizations.

In general, a very liberal policy is followed in allowing representation on the working committees. As a result, some of them are very large, in extreme cases containing as many as 50 or 60 members. The chairman decides the detailed questions which arise in the formation of a working committee. The central office digests the information available on the subject for the use of the working committee. When agreement is reached in the committee on the draft of a standard it goes to the central office for editorial work. There it is scrutinized to see whether it is consistent with other standards, whether points have been included which concern other working committees, and whether the drawings and nomenclature are in approved form, etc.

After this editorial work, the central office has the draft of the standard put into proof form. It is then

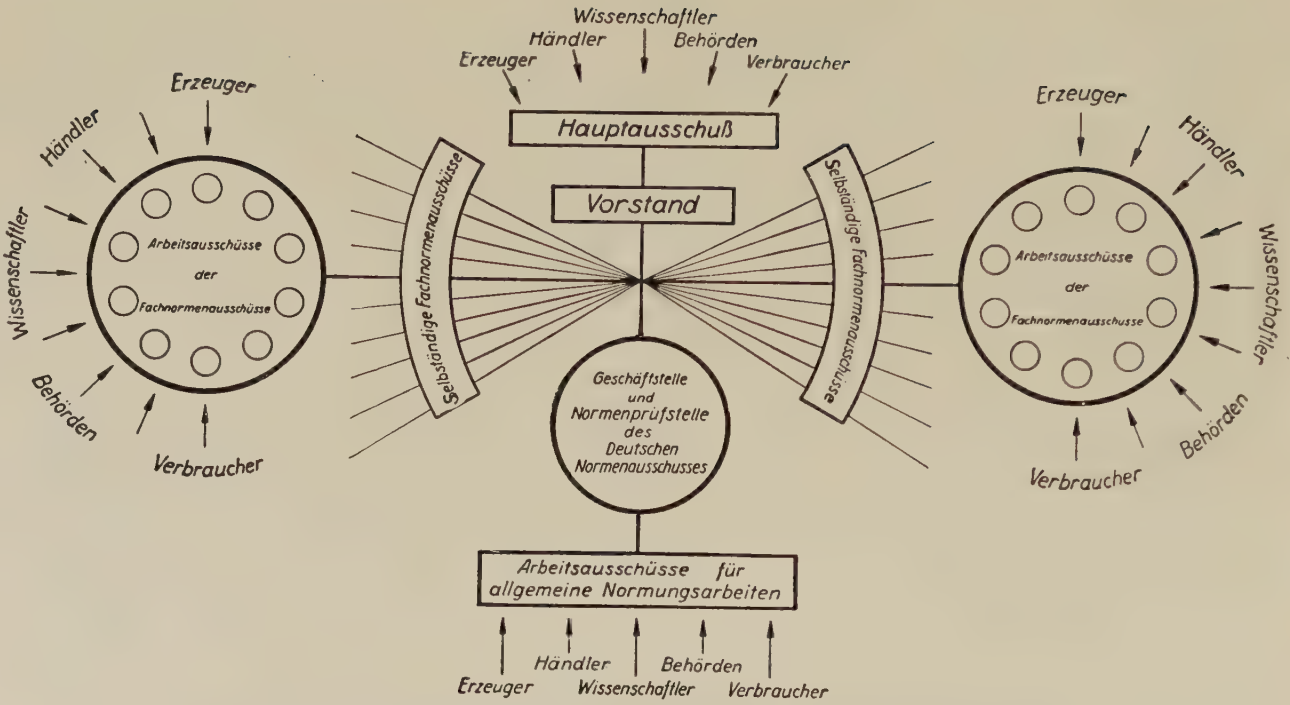



FIG. 15.—Organization of the *Deutscher Normenausschuss* (German Standards Committee).

reviewed by an official clearing-house committee (*Normenprufstelle*) which contains a representative from each major line of work being carried on by working committees. If any change in substance has been made, it goes back to the working committee. If no such change has been made, it is published in the journal devoted to the subject as a tentative proposal (*Entwurf*). Criticisms resulting from publication come to the office, where they are analyzed and forwarded to the chairman of the working committee. The committee decides whether new editions of the proposal are necessary.

Upon recommendation of the working committee, the standard is mailed to the members of the Executive Committee with a supporting statement. With their approval, it is published as an official proposal (*Vorstandsvorlage*) in the *Maschinenbau*, the official publication medium of the *Normenausschuss*. Six weeks are then allowed for criticisms, when a standard is finally published unless additional important criticisms are received, which happens very rarely at this stage.

When the standards upon which a working committee has been engaged are published, the committee makes a general report, and is ordinarily discharged.

**Publication of Standards.**

The standards are published under the general designation of "German Industrial Standards" (*Deutsche Industrie Normen*, usually contracted to the slogan *Dinorm*). It is significant that everywhere in Europe the phrase *industrial standardization* seems to be replacing the older *engineering standardization*. The word *engineering* does not occur in the name of the German organization: *Deutscher Normenausschuss*.

The Germans were the first to publish standards in the looseleaf form. The work is so divided as to make each sheet as nearly independent as possible. The idea is

that the sheets shall be issued directly to designers, draughtsmen, and foremen, in much the same way as working drawings. The standards may also be obtained printed on tracing paper for the use of firms who wish to reproduce them with additional data for the use of the members of their staff. The cost of standard sheets varies from 12 to 25 cents, according to quantity, and that of tracing paper sheets is 50 cents. The sale of sheets amounts to approximately $23,000 per month. Emphasis is laid upon the uniform style and appearance of the published standards, and this is used for publicity purposes in much the same way that slogans and trademarks are used by private firms.

The published list of standards and proposals is very complete, containing alphabetical, subject, and numerical indexes, together with complete references to the publication of the successive issues of projects, etc. This list also contains the names of manufacturers whose products conform to the NDI standards. For insertion in the list of manufacturers a charge of about $38 per line is made.

From almost the first, the *Normenausschuss* has had a periodical publication dealing with standardization. Formerly, it was a separate publication but now it forms a section of *Maschinenbau*, a journal dealing with general questions of production and efficiency engineering, issued by a very large publishing house under the control of the *Verein deutscher Ingenieure*, which issues nearly a score of engineering and technical journals. The communications from the Normenausschuss form a separate section in this journal under the heading *Mitteilungen des Deutscher Normenausschuss.* It appears semi-monthly and averages about 16 quarto pages per issue. In it all proposed standards are published twice: first, as a tentative proposal of the working committee (*Entwurf*), and, second, as an official proposal, with the authority

of the *Vorstandsvorlage* (executive committee). Considerable explanatory matter is often added. It also contains discussion of proposed standards, notices of meetings, abstracts of minutes, and news items dealing with standardization both from Germany and from other countries.

Next to the American Engineering Standards Committee the German organization is the most decentralized of the national standardizing bodies. The Germans have two types of working committees corresponding to the sectional committees of the American Engineering Standards Committee. The first they call *Arbeitsausschüsse* (working or general committees). These committees deal with subjects which are common to two or more industries or branches of industry.

The other type of committee they term *Fachausschuss* (special-industry committee). These have to do primarily with standardization work peculiar to a single industry or branch of industry. They are closely affiliated with, but are not strictly an organic part of, the central body. They are organized, not by the Normenausschuss, but by one or more technical or trade associations concerned with the particular subject in hand. In general, the standards, both in tentative and in final form, are published by the organization responsible. In most cases, the final standards are published in looseleaf form modeled closely after that of the German industrial standards of the Normenausschuss itself. Some of these standards have been approved by the Normenausschuss and published by it in its regular series, the organization responsible for the origination of the standard being indicated on the sheet.

The efficient coordination of the work of the special industry committees, and the many problems of a clearing-house nature which are involved present various administrative difficulties. The Germans are undertak-

ing a very considerable amount of reorganization of the relations of these committees to the central body, and, in fact, it is not unlikely that such reorganization will take considerable time, if, indeed, it does not prove to be an almost continuing process.

The closeness of affiliation of these committees to the central body is a variable one. In general, they submit their proposals to the office of the central body for criticism before adoption. In this way, much is accomplished in making them consistent with the regular series of German industrial standards.

It seems to be the policy, at least of the engineers in the central office, not to push the work of the special-industry committees, except in those cases where industrial conditions make it necessary, but rather to put the emphasis in what is considered the more fundamental work of the general standards, which will also serve as a basis for the standardization work in the special industries.

It is interesting that there appears to be no haste or anxiety in bringing the standardization work of special industries under the auspices of the central body. It seems to be considered that the prestige of the latter and its support by the German industries is so firmly established that it is inevitable that all such standardization work will eventually be placed under its general auspices.

In Germany, by far the greater part of the work of the central body up to the present time (1928) has dealt with dimensional standardization. A larger percentage of the work of the special-industry committee has to do with specifications, methods for testing, and the simplification of types, sizes, etc. Much work of the latter kind is being carried out and a special word has been introduced for it—*typung*. Sixty per cent of the standards deal with the machine industry, and the balance, with civil

and electrical engineering, and the automotive and locomotive industries.

Between $50,000 and $75,000 are spent annually by the *Deutscher Normenausschuss* to promote standardization, and the standards are widely used.

The German standards are submitted to the criticism of technical publications interested in the particular question, so that groups not represented in the comparatively restricted labor committees may be able to voice their proper objections. On the basis of such criticism, a second outline is published in the technical periodicals. In case no further criticism follows, the resultant standard forms are submitted to the general committee of the German Standardization Committee in which all the important business groups are represented, and then issued as a final standard.

From 1½ to 5 years are required from the time the project is taken up to the final issue of such a standard form. Most of the standards reached their final stage within 2 to 3 years.

So far, over 2,200 standards, most of them dimensional, have been established. Most of them are published in looseleaf form for convenient direct use in shop and draughting room. More than 100,000 sheets are sold per month.

In Germany, the organization is independent of the Government and derives its support, half a million gold marks ($125,000) annually, from contributions from manufacturers and from the sales of its publications. It is stated that, generally speaking, the German manufacturers, probably because of their technical training, appear to take more interest in industrial standardization than the generality of firms in this country and Great Britain do, and they make very extensive use of their standardizing organization for the purpose of standardizing their manufactures.

There are now more than 1,000 firms in Germany which have made a systematically organized standards department an official part of their administrative organization. In all the great firms, this department reports directly to the general management. This has given the German work a momentum and an effectiveness which is perhaps equaled in no other country. Many of the stronger trade associations maintain engineers in the office of the central body.

As mentioned on page 96, *rationalization* is rapidly becoming a leading business factor in Germany and other European countries.

The most significant and the most completely developed organization of the German rationalization movement is the *Deutscher Normenausschuss*, described above, which is a technical body.

The *Reichskuratorium für Wirtschaftlichkeit, R.K.W.* (National Economic Board) is the national headquarters for all rationalization work in Germany. It is an economic rather than a technical body. The national leaders of industry, commerce, banks, and transportation companies are members of the board.

The *Reichskuratorium* is divided into three important organizations:

1. *Ausschuss für wirtschaftliche Fertigung, AWF.*
2. *Reichsausschuss für Lieferbedingungen, RAL.*
3. *Ausschuss für wirtschaftliche Verwaltung, AWF.*

1. The *Ausschuss für wirtschaftliche Fertigung* (Committee on Economics of Production), founded originally at the suggestion of the *Verein deutscher Ingenieure,* is now directly under the *Reichskuratorium.* Its object is to investigate the technical methods and processes of industry, not only for a definite branch of business, but for whole categories of common interests.

2. The *Reichsausschuss für Lieferbedingungen* (National Specification Committee) sets up standardized purchase specifications for commodities commonly used in German industrial and economic life, such as *food-stuffs, textiles, leather, paper paints, soap, packing materials, etc.*

The specifications include the necessary characteristics and limits of composition, methods of testing, storage, use, etc. The specifications are the result of collaboration between the producer, vendor, and user. Care is taken to provide specifications that are commercially practicable from a mass-production standpoint, so that the ultimate user will be ensured a low price.

In many cases it is impracticable to develop simple methods of analysis and test in time to include them in the specifications when they are ready for publication. In such cases, the specifications proper, and the methods of tests applying, are issued separately. The setting up of the simple test methods is done in collaboration with the *Ausschuss für Wirtschafliche Fertigung,* to avoid unnecessarily complicated methods, arrangements, etc.

The purpose of the purchase specifications is to advise the user or importer in regard to such properties, composition, etc., of the material or article as may be necessary for its economic use.

The German National Specification Committee is very similar in purpose and procedure to the Federal Specifications Board of the Bureau of the Budget of the United States, except that the use of the specifications promulgated is not mandatory.

3. The *Ausschuss für wirtschaftliche Verwaltung* (Committee on Economics of Management) endeavors to find and introduce the most suitable means and methods in the field of management, in collaboration with both private and public interests in science and industry, the object being to lower the element of cost.

The main body is divided into several special committees (*Fachausschüsse*), as follows:

*a.* *Ausschuss für Bürowesen* (office organization).
*b.* *Ausschuss für Abrechnungswesen* (accounting).
*c.* *Ausschuss für Arbeitsvorbereitung* (planning work).
*d.* *Ausschuss für Lagerwesen* (storing).
*e.* *Auschuss für Terminologie* (nomenclature).
*f.* *Auschuss für Symbolik* (symbolism).

### ASSOCIATION FRANÇAISE DE NORMALISATION. A.F.NOR

(French Standardization Association)

This association was formed on June 22, 1926, and is intended to include *syndicates* especially, that is to say, the representatives of manufacturers, as it is essentially industrial in its aims and resources.

The French standardizing body which preceded the *Association française de Standardisation* was the *Comité permanente de Standardisation* (Standing Committee on Standardization), which functioned under the Minister of Commerce from 1918 to 1924. This body was formed by the French Government and its work was primarily for the government departments.

The *Comité permanente de Standardisation*, while active, issued a considerable number of standard specifications in connection with metallurgy, wood, naval and mechanical constructions, building construction, etc., but it has been inactive for the past 4 years.

The adherents of the *Association française de Normalisation*, the successor of the *Comité permanente de Standardisation*, are as follows:

1. Le Comité des Forges (Metallurgical Industry).
2. Le Comité des Houillers (Coal Mines).
3. L'Union des Syndicats d'Électricité (Electrical Syndicates Union).

4. Le Syndicat des Entrepreneurs de constructions métalliques (Contractors of Metal Structures).

5. L'Union des Voies ferrées d'interêt local (Union of Local Railways and Street Railways).

6. Le Syndicat des Constructeurs de navires et de machines marines (Syndicate of Shipbuilders and Manufacturers of Marine Engines).

7. Le Syndicat des Constructeurs de material de chemins de fer (Manufacturers of Railway Material).

8. Le Syndicat des Industries radio-électriques (Syndicate of Radio Industries).

9. Le Syndicat des Entrepreneurs de Reseaux et Centrales électriques (Syndicate of Contractors of Electrical Systems).

10. Le Comptoir sidérurgique de France (The French Metallurgical Agency).

The *Association française de Normalization* is not a *standards-making body.* It is definitely prohibited from either establishing or publishing a standard of any kind. It serves merely to *coordinate* the activities of the *French standardizing groups.*

Under the terms of the organization of the Association, its object is the grouping of the bodies in France concerned with standardization, the representing of these bodies before public authorities and foreign associations, and, finally, of encouraging standardization work in France.

The Association has three kinds of members: *federation, collective associate,* and *individual associate.* A federation member is a supporting trade association, such as a governmental or large private administrative body; a collective associate is a member representing several trade associations; an individual associate member is a person interested in the standardization movement and taking an active part in the work of the association.

All work is conducted by a *general assembly* made up of individual associates and representatives of the federation and collective associate members. Each individual associate has *one vote*, and each federation 10 *votes*, irrespective of the actual number of persons in each delegation.

Standardization projects relating to structural steel shapes, screw threads, bolts and nuts, machine parts, steel rails, and various non-ferrous metals have been acted upon by the association, which has also given consideration to a standard series of "preferred numbers."

### AMERICAN SOCIETY FOR TESTING MATERIALS

Organized for the purpose of promoting the knowledge of materials of engineering and the standardization of specifications and methods of testing, *standardization* is a most important function of the society. Practically all of the society's committees are actively engaged in the work of standardization and preparation of specifications. The headquarters of the society are at 1315 Spruce Street, Philadelphia, Pa.

Standards of the society are published triennially in a book of *Standards* (Part I on Metals and Part II on Non-metallic Materials); and supplements to this are issued in intervening years. Tentative standards, which are offered for publication to secure criticism and comment, are published in the annual *Proceedings* and collected each year in a book of *Tentative Standards*.

Among the current activities of the society, the development of the following *standards* may be cited as of outstanding importance: For metals of high-temperature service; zinc-coated and other metallic-coated products for increased resistance to corrosion; magnetic testing and analysis of metals; ferro-alloys; metallic materials for electric heating; die-casting alloys; cement, concrete,

and concrete products; brick, hollow tile, and other ceramic products; refractory materials; preservative coatings, including paints, varnishes, pigments, vehicles, and paint thinners; petroleum products; road and paving materials; waterproofing and roofing materials; electrical insulating materials; textile materials; slate; and naval stores.

There are many other national standardizing bodies in the United States, but they are of relatively minor importance from an industrial standpoint. For details concerning these, see "Standards Yearbook" for 1927 and 1928.

### INTERNATIONAL STANDARDIZING BODIES

A good deal has recently been said of the advantage of international standards, and the subject is evidently worthy of further study, though the advocates of so-called international standards often really mean the adoption of their own established national standards by other countries—a very different proposition.

While there are a dozen or more international organizations doing standardization work of one kind or another, there are but three movements which need consideration from the point of view of industrial standardization. These are:

1. International Electrotechnical Commission (I.E.C.).
2. International Commission on Illumination.
3. The direct cooperation between the national standardizing bodies which, it has been proposed, should be organized into a general worldwide standards association.

#### International Electrotechnical Commission

The body was established in 1906, its original object being the *standardization of nomenclature and rating of apparatus and machinery in the electrical field.* Recently the work has been extended to include the general sub-

ject of "prime movers." There are now 24 countries adhering to the International Electrotechnical Commission, each country cooperating through a national committee.

The affairs of the International Electrotechnical Commission and the methods of carrying out its objects are determined by a council. Between the meetings of the council, a Committee of Action, appointed by the president, is in general administrative charge. The Plenary Assembly is composed of official delegates from each country.

The International Electrotechnical Commission has, so far, established the following seven standards:

1. International symbols, adopted at Berlin, September, 1913, revised December, 1920.
2. International standard of resistance for copper, adopted at Berlin in 1913, revised edition published in March, 1925.
3. International Electrotechnical Commission rules for rating of electrical machinery.
4. International graphical symbols for heavy current systems.
5. Standard voltages.
6. International Electrotechnical Commission specification for traction motors.
7. International Electrotechnical Commission dimensions for standard bayonet bases and sockets for incandescent electric lamp bulbs.

The National Committees of the International Electrotechnical Commission are organized differently in the different countries. In some countries, for example, Great Britain, the National Committee of the International Electrotechnical Commission, is an organic part of the national standardizing body; in other countries, the relation is looser, and in still others, there is no organic relation at all. The last is the case in the

United States. Until 1921, the United States Committee of the International Electrotechnical Commission was organized wholly by the American Institute of Electrical Engineers. Since that time other organizations have nominated members. At present, there are 44 members, of whom 25 are designated by the American Institute of Electrical Engineers. The United States Committee is now considering plans for the expansion of the functions of the International Electrotechnical Commission to cover the entire field of international cooperation in industrial standardization.

### International Commission on Illumination

This body was organized in 1913 and is occupied with questions of *nomenclature* and *standards;* with the establishment of those uniformities in lighting practice which, in each country, would ultimately lead to legislature enactments for the factory, the school, and for automobiles; and with cooperative and intensive study of methods of measurement.

### Proposed International Standardizing Body

There has been considerable informal cooperative interchange of information on work in progress directly among the National Standardizing Bodies. Four conferences have been held, one in London in 1921; one in Zurich in 1923, one in New York in 1926, and one in London in 1927. Since 1921 most of the national bodies have been acting as sales agents for the standards of the other bodies. The formation of a definite International Standardization Organization composed of the national bodies is now receiving serious consideration, and it now (1928) seems probable that an *International Standards Association* will soon be formed.

Any desired information relating to standardization in foreign countries can be obtained from the American Engineering Standards Committee, Engineering Societies Building, 29 West Thirty-ninth Street, New York City.

## CHAPTER VIII

# INTERNATIONAL AND NATIONAL STANDARDIZING LABORATORIES

The importance of maintaining National Scientific Institutions for research and technical work in connection with standards and standardization, and the application of precise measurements to the industries, has been recognized by the leading countries of the world.

### BUREAU INTERNATIONAL DES POIDS ET MESURES

(International Bureau of Weights and Measures)

The most momentous event in the entire history of weights and measures was the creation, in 1875, of an international organization for the establishment of a worldwide uniformity in standards.

Although the French metric system had been adopted in many countries, the copies of the legal French standards of length and mass in use differed to such an extent that difficulties arose in the work of geodetic surveying. The relation of the several copies to their prototypes in France was not known with a degree of precision in keeping with the requirements of science. Furthermore, the standards of the Archives of France, made in the eighteenth century were not constructed with the degree of perfection attainable in 1870.

The French government, therefore, invited other countries to send delegates to a conference to be held in Paris on August 8, 1870, to consider the advisability of constructing new metric standards. Twenty-four coun-

tries, including the United States, designated delegates, but, on account of the outbreak of the Franco-Prussian war, the conference was abandoned.

At a second conference in 1872, at which 30 countries were represented, it was decided that new meters and new kilograms should be constructed to conform to the original standards of the Archives of France, and a permanent committee was appointed to carry out that decision. At the request of this permanent committee, the French government called a diplomatic conference, which was held in March, 1875, at which 19 countries were represented. On May 20, 1875, 17 of the 19 countries signed a Convention for the establishment and maintenance of a permanent *Bureau international des Poids et Mesures*, which was to be located at Paris, France. The bureau was placed under the direction and supervision of an International Committee of Weights and Measures, which, in turn, was placed under the control of a General Conference for Weights and Measures composed of the delegates of all the contracting nations.

The International Bureau of Weights and Measures is recognized as the highest tribunal on weights and measures, and is located on international territory at Parc de St. Cloud, Sèvres, near Paris.

The functions of the Bureau as defined by the convention are:

1. All comparisions and verifications of the new prototypes of the meter and kilogram.
2. The custody of the international prototypes.
3. The periodical comparison of the national standards with the international prototypes and with their test copies, as well as comparisons of the standard thermometer.
4. The comparison of the prototypes with the fundamental standards of non-metric weights and measures used in the different countries and for scientific purposes.

5. The sealing and comparison of geodetic measuring bars.

6. The comparison of standards and scales of precision, the verification of which may be requested by governments or by scientific societies, or even by constructors or men of science.

In 1921 the scope and functions of the International Bureau were broadened, through amendments to the treaty, which were subsequently ratified by the several signatory powers, so that the supervision of certain electrical and thermometric units and standards is now included.

The International Prototype Meter and Kilogram, and the test copies of same, are deposited in a subterranean vault at the International Bureau. Four special keys are successively required to open the vault and three of them are in the custody of foreign members of the International Committee. The vault is opened every 6 years, during the meeting period of the International Committee, to demonstrate that the International Prototype Meter and Kilogram are in safe preservation.

The expense of constructing, equipping, and maintaining the International Bureau and the expenses of the committee are defrayed by contributions from the contracting nations, the amounts of which are in proportion to the actual population of the nations participating.

A special committee of the international organization was entrusted with the construction of the meters and kilograms. After making three preliminary meters and three preliminary kilograms, 30 meters and 40 kilograms were constructed of the alloy of 1874 (90 per cent platinum, 10 per cent iridium), and compared with the meter and kilogram of the Archives. This work was completed in 1889. At a general conference held in that year at Paris, the work of this committee was approved, and the meter and the kilogram which were found by a long series

of observations to agree most closely with those of the Archives were declared to be the *International Meter* and the *International Kilogram*, respectively. From that date the Standards of the Archives ceased to be reference standards. They are now of historical interest only. The other standards, certified in terms of the adopted international prototypes, were distributed by lot to the contributing countries.

The copies of the international standards allotted to the United States were deposited in the Office of Weights and Measures in Washington, in 1890, but were transferred to the National Bureau of Standards upon its creation in 1901.

### EARLY FOREIGN NATIONAL STANDARDIZING LABORATORIES

The earliest foreign national official agency for the establishment of fixed, accurate standards of weights and measures was the *Normal-Aichungs-Kommission* of Germany, which was established in Berlin in 1868. Its purpose was declared to be

". . . to regulate the system of inspection of weights and measures throughout the North German Confederation, to construct and provide standards and the necessary measuring apparatus for the local bureaus, to fix regulations in regard to the system of inspection, and to provide for the safe custody of the standards."

In 1871, Austria established a *Normal-Aichungs-Kommission;* in 1878, Russia established a *Central Chamber of Weights and Measures*, which was reorganized in 1893; and in 1879 England reorganized its Standards Department, all of which institutions had functions similar to the *Normal-Aichungs-Kommission* of Germany.

### Physikalisch-Technische Reichsanstalt

(National Physico-technical Institute)

The German *Physikalisch-Technische Reichsanstalt* at Berlin-Charlottenburg, was established in 1887, as a

national physical laboratory and standardizing bureau, and for testing and investigations in connection with scientific and technical standards other than weights and measures.

In 1918, the name of the German *Normal-Eichungs-Kommission* was changed to *Reichsanstalt für Masse und Gewicht* (National Institute of Weights and Measures). In 1923, it was transferred to the *Physikalisch-Technische Reichsanstalt*, which was at that time reorganized into the following divisions:

1. Weights and Measures.
2. Electricity.
3. Heat.
4. Light.
5. Radioactivity.

The *Physikalisch-Technische Reichsanstalt* functions under the Ministry of the Interior. It has a personnel staff of 262, and an annual budget of nearly $238,000.

### Staatliche Materialprüfungsampt

(Public Material-testing Laboratory)

The *Materialprüfungsampt*, a Prussian public testing laboratory at Berlin-Dahlem, is concerned with the investigation and testing of structural, engineering, and other materials.

### National Physical Laboratory

The Kew Observatory, established in 1871 at Richmond, Surrey, England, originally as an astronomical observatory, and then as a meteorological observatory, also became later a more general testing bureau under the Royal Society of London. In 1889 the *National Physical Laboratory* was established at Teddington, as a govern-

ment institution, and it took over certain functions of the Kew Observatory. It then became a general standardizing laboratory where standards and measuring instruments in use in science and trade may be verified, and research work may be undertaken when required for the needs of the laboratory or when regarded as of distinct value to the public generally. The departments of the National Physical Laboratory are as follows:

1. Physics.
2. Electricity.
3. Metrology.
4. Engineering.
5. Metallurgy and Metallurgical Chemistry.
6. Aerodynamics.
7. The Froude National Tank (Hydrodynamics).

The National Physical Laboratory has a personnel of 570, and is administered by a General Board, headed by a chairman.

### Board of Trade Standards Department

Great Britain also maintains the *Standards Department of the Board of Trade*, London, which is in charge of the standards and inspection service of the trade weights and measures.

### Laboratoire d'Essais

(National Testing Laboratory)

The *Laboratoire d'Essais mécaniques, physiques, chimiques, et des machines, du Conservatoire National des Arts et Métiers*, while not as extensive as the British National Physical Laboratory, or the German *Physikalisch-Technische Reichsanstalt*, is charged with similar duties.

The Laboratoire d'Essais is the successor of the *Laboratoire de Méchanique*, which was created in 1854

by General Maurin. It is the national testing laboratory of France, and was completed and developed by the law and the decree of July 9, 1901. It is located in Paris.

The *Laboratoire* covers a very general field, as follows: physics (except electricity); metals; other materials of construction, such as wood, stone, cement, and lime; machines (except electrical machines and accessories); raw vegetable materials; fuels; lubricants: and illuminating oils.

The work is divided into five sections, as follows:

1. Physics (except electricity).
2. Metals.
3. Materials of Construction.
4. Machines (except electrical, and accessories).
5. Chemistry.

The *Laboratoire d'Essais* is directed by a President, assisted by a Technical Commission, and functions under the Ministry of Public Instruction and Fine Arts. The annual budget of the institution (1926) was more than $200,000 exclusive of a grant from the Civil Engineers' Society of France. It has a personnel of 180.

### Laboratoire central d'Électricité

(Central Electrical Laboratory)

The *Laboratoire central d'Électricité* was founded by the decree of Feb. 24, 1882, and began operations in 1888 in Paris. It functions under the *Société française des Électriciens.* There are four divisions, and a personnel of 21 persons, and the budget for 1926 was over $75,000.

The *Laboratoire central d'Électricité* is not a government institution, but it collaborates closely with the *Laboratoire d'Essais,* the *Phykalisch-Technische Reichsanstalt,* the

*National Physical Laboratory*, and the *National Bureau of Standards.*

### National Bureau of Standards

With the development of science and the growing complexity of industry and commerce in the United States, the need for stable and accurate standards not only of weight, length, and capacity but also of power and energy, became more and more apparent. The scientist, the manufacturer, the merchant, the public officer, and the consumer—all are required to have recourse to such standards in scientific, industrial, and mercantile operations, and in the enforcement of laws.

There was urgent need for numerous standards as well as for apparatus for tests and comparisons. It was necessary to determine the accuracy of meters, balances, precise measuring apparatus, graduated glassware, pressure gauges, thermometers, barometers, metrological apparatus, photometers, gas and water meters, apparatus for electrical measurements, oil testers, instruments used in surveying, navigation and hydrography, apparatus for testing the strength of materials, and a great variety of others. It became more and more important as science, industry, and commerce advanced that the graduations and indications of these instruments should agree with fundamental standards, and that such standards should bear the voucher of governmental supervision and control.

Other countries, especially Germany, had for many years made great progress in the direction of supplying these standards, and it had become a practice for American scientists, engineers, manufacturers, and merchants, and even for our government officials, who had need for such certified standards, to send their instruments and apparatus abroad for testing and comparison. This involved much expense, delay, inconvenience, and some

humiliation, but it was the only means of obtaining satisfactory standards in many lines of instruments and apparatus prior to 1901.

In the United States, the meagre provisions made by Congress for standardization work prior to that time made it impossible for the Office of Standard Weights and Measures to do more than render a very limited service to the national government and to the states and practically no service to private industry.

In order to put the United States on a parity with other leading countries in meeting the demands of science and industry for standardization, the Secretary of the Treasury, in 1900, submitted to Congress the draft of a bill providing for the establishment of a National Standardizing Bureau, with an appended statement of the conditions necessitating such legislation.

The bill provided that the Office of Standard Weights and Measures should be known as the *National Bureau of Standards*, removing it from the supervision of the Superintendent of the Coast and Geodetic Survey, but leaving it for the time in the Treasury Department.

The functions of the proposed bureau, as specified in the bill, comprised:

1. Custody of the standards.
2. Comparison of the standards used in scientific investigations, engineering, manufacturing, commercial, and educational institutions with the standards adopted or recognized by the government.
3. The construction, when necessary, of standards, their multiples and subdivisions.
4. The testing and calibration of standard measuring apparatus.
5. The solution of problems which arise in connection with standards.
6. The determination of physical constants and the properties of materials when such data are of great

importance and not to be obtained of sufficient accuracy elsewhere.

It was provided in the bill that the Bureau was to exercise its functions for the government of the United States, for any state or municipal government within the United States, or for any scientific society, educational institution, firm, corporation, or individual within the United States requiring the use of standards or standard measuring apparatus.

Immediately upon its creation, in 1901, many demands were made upon the Bureau for its services, and Congress, by increasing its appropriations from year to year enabled the Bureau to enhance its facilities and expand its work. The direction of the Bureau's growth was determined by the relative urgency of the several lines of its activities.

The Bureau's predecessor, the Office of Standard Weights and Measures, originally dealt only with standards of weights and measures. With the establishment of the National Bureau of Standards came the task of establishing temperature standards for the country. These tasks were followed in succession by the establishment of electrical standards, photometric and other optical standards, standards for a large variety of materials, such as metal products, cement, paper, leather, and, in fact, of nearly everything of technical and industrial interest that was bought on quality specifications. This work of *standardization* is accomplished largely through the cooperation of experts of the Bureau with the engineering and industrial organizations of the country, resulting in the formulation of specifications which define the standard materials or articles.

The basic function of the United States National Bureau of Standards is to establish and maintain the national standards of quantitative measurement—usually termed *weights and measures.* The Bureau is the

custodian of the country's official standards of measurement. When necessary, it constructs, tests, and calibrates new measures, and compares the measuring apparatus used in scientific investigations, and in engineering, manufacturing, and commerce, with the official standards. The statutes authorize the Bureau to conduct scientific investigations of problems connected with the development and application of standards, and to determine the properties and characteristics of different materials, such as the thermal expansion of materials, the viscosity of lubricating oils, the melting point of metals, the boiling point of liquids, the conductivity of insulating materials, the tensile strength of steel, and the like. Generally speaking, this work is limited to occasions when the data are of urgent importance to scientific or manufacturing interests and are not readily obtainable elsewhere. While there is invariably an immediate and practical objective, yet facts and principles are constantly discovered of immense value as contributions to the general fund of scientific knowledge.

Essentially, the National Bureau of Standards is a scientific and technical laboratory for service to the industries of the country and to the various departments of the Government. It has 10 major and 7 minor buildings, a staff of 850 persons, a library of 31,000 volumes, and 730 periodicals are received. Some 350 specialized scientists trained in physics, chemistry, and engineering are at work on problems involving the quality of materials and the testing of the commodities of commerce. There are 62 research associates from industry and 1,000 advisory committee experts from industry, and scientific, technical, and engineering societies. The bureau is by far the largest institution of the kind in the world, and its annual budget is about $2,500,000. It is a part of the Department of Commerce.

The Bureau now is engaged in research not only in connection with standards of weights and measures and the physical and chemical properties of materials, but also in connection with standards of quality, standards of practice, and standards of performance. The scope of activities of the United States National Bureau of Standards is very closely that of the *Physikalisch-Technische Reichsanstalt*, the *Chemisch-Technische Reichsanstalt*, and the *Materialprüfungsamt*, of Germany. The bureau takes a very active part in *national and international standardization work.*

The development of standards of quality, practice, and performance had its beginning in the custom of submitting samples of materials purchased by the various departments of the Government to the Bureau of Standards for test. This custom has been encouraged both by the Bureau itself and by Congress, and appropriations are now made specifically for the purpose. Obviously, the tests could be made only by determining and establishing definite *specifications* for particular materials as standards to be met by manufacturers and dealers. These become standards of quality (strength, durability, color, etc.) as applied to such materials as metals, rubber, leather, textiles, paper, or cement; standards of performance (efficiency, serviceability, etc.) as applied to machinery, technical and scientific apparatus, vehicles, and the like; and standards of practice (safety, economy, convenience, etc.) as applied to the operation of utilities and other services. There are 350 researches in progress (1928), and 180,000 tests per year are made.

The scientific work of the Bureau of Standards is largely in the fields of physics and chemistry, and includes many branches of both these sciences. The greater part of the work is directed toward the practical application of scientific principles, and might properly be called technical experimentation. There are laboratories not

only for investigations in the phenomena of light, heat, electricity, etc., but also for testing and experimenting with machinery and apparatus in accordance with the principles developed from the study of these phenomena, and for testing all manner of raw and manufactured products. There are shops where apparatus and tools for investigations and tests are made and repaired. Large rooms are devoted to small-scale manufacturing plants. These include plants for making optical glass and pottery; a cement plant; paper, textile, and rubber mills; and a foundry. Each of these is equipped with the machinery for performing manufacturing operations on a small scale.

Substantially, half of the resources of the National Bureau of Standards is expended in the testing of materials, instruments, and equipment. This is largely for the Army and the Navy, and the other departments of the government, but much testing work is done for industry, or for the direct benefit of the public. The work varies from making tests of aeroplane engines under actual flight conditions to the testing of clinical thermometers. The bureau maintains uniformity throughout the country by testing all master standards of weight. It operates test cars to calibrate the master scales used by the railroads, upon which freight charges are based. It tests the weighing equipment at mines. It tests and certifies virtually all the radium produced in the country.

The scientific and technical staff of the bureau is organized in nine divisions; electricity; weights and measures; heat and power; optics; chemistry; mechanics and sound; organic and fibrous materials; metallurgy; and clay and silicate products. The work of these divisions varies according to the nature of their fields of research; that is, the classes of standards involved and the processes and materials used. Special divisions take

care of technical work not included in the scope of the regular nine divisions, and there are divisions for handling office administration, operation of plant, and construction. A brief résumé of the work of these divisions is as follows:

**1. Electricity Division.**

The work in the field of electricity engages the attention of more members of the Bureau's scientific and technical staff than any other single activity. The electricity division works on problems connected with the establishment and maintenance of the fundamental standards upon which electrical measurements are based and the development and improvement of subsidiary and derived standards. This includes, of course, the intercomparison of standards, research in the methods of measurement of the various electrical properties—electromotive force, resistance, current, conductivity, etc.—and the determination of electrical and magnetic properties for different substances. The division tests electrical instruments and apparatus, such as lamps, batteries, and transformers, and works on improvements in their design and construction. It also deals in the same way with telephone, radio, and photometric apparatus. It serves as a clearing house for service standards for telephone and electric companies, public utility commissions, and municipalities. It has formulated a safety code intended to be adopted by States and municipalities for the proper safeguarding of the operation of electrical public utilities.

**2. Weights and Measures Division.**

The weights and measures division has the custody of the national prototype standards of length and mass, and is concerned largely with the comparison of working standards with these reference standards. It prepares

the specifications for standardizing weights and measures, and determines *tolerances* or limits of variation allowable in their use. It designs, constructs, and improves apparatus for recording measurements of length, mass, time, area, volume, density, and pressure. Researches are conducted to define more accurately the value of certain of the *physical constants* derived from measurements of length and mass. The division calibrates weighing and measuring apparatus by comparison with the reference standards. It cooperates with state and local governments in maintaining standards and confers with them in regard to proposed regulatory measures.

**3. Heat and Power Division.**

The heat and power division is charged with the performance of the bureau's duties with respect to heat-measuring and heat-utilization devices. It is engaged in developing and perfecting the specifications for standardizing temperature-measuring instruments and in constructing and testing such instruments. It also determines for various substances the *physical constants* which are related to heat, for example, specific heat, latent heat, heat of combustion, and melting and freezing points, and works out fundamental engineering formulas involving the use of these constants. The division has devised apparatus for making fire tests of structural materials and conducts such tests when required. It investigates the problems connected with internal-combustion engines and their fuels and lubricants.

**4. Optics Division.**

The optics division deals primarily with problems arising in connection with the measurement of light. It seeks to discover the qualities of various substances in transmitting, reflecting, radiating, refracting, and absorbing light. It develops instruments and apparatus for

the measurement of light and the study of phenomena connected with light, such as the spectrometer, the polarimeter, the colorimeter, etc. It investigates optical instruments, photographic equipment, and general radiometric instruments, with the purpose of arriving at standards of performance and of improving the apparatus. The use of the polarization of light in the manufacture and testing of sugars has led to study by the optics division of the processes of manufacturing sugar, and the division assists the Treasury Department in the supervision of the sugar laboratories of the Customs Service. Because the phenomena of optics lend themselves to a ready interpretation of the physics of the atom, the optics division also engages in investigations relating to the *ultimate structure of matter*. Since different forms of matter are characterized largely by differences in atomic structure, advances in such knowledge are of the greatest importance to science and technology.

**5. Chemistry Division.**

The chemistry division is in charge of the chemical tests made by the Bureau and the research which is primarily chemical in its application. The tests include those made at the request of various departments of the Government, as well as those made as an incident to the Bureau's own investigations. The division makes chemical analyses to determine the composition and purity of materials, carries on investigations in electrochemistry, prepares pure materials for *standardization* work, develops specifications for the chemical properties and *constants*, and devises methods and apparatus for chemical analyses and tests.

**6. Mechanics and Sound Division.**

The mechanics and sound division conducts investigations relating to mechanics, engineering instruments,

aeronautics, aerodynamics, sound, and the properties of fabricated metals. It prepares specifications for standard performances of engineering, aeronautic, and sound-ranging instruments; devises methods and apparatus for testing such instruments and their work; and itself makes many tests and measurements. It carries on investigations in the soundproofing properties of building materials, in the experimental development of aircraft instruments, and in aerodynamics, particularly with respect to the resistance of the air to aircraft and projectiles. It makes tests to determine the strength and other properties of fabricated metal structures.

**7. Organic and Fibrous Materials Division.**

The organic and fibrous materials division makes tests of materials, such as leather, rubber, paper, and textiles. The tests are physical and chemical, and include microscopic and photomicrographic analyses. They are undertaken chiefly at the request of other governmental agencies and have for their purpose the development of *standard specifications* to be used in Government purchases and the improvement of manufacturing processes. The division is completely equipped for the manufacture of paper, rubber, and textiles on an experimental scale.

**8. Metallurgy Division.**

The metallurgy division has, for its function, investigational work with metals and alloys to determine their structure and their behavior under various conditions. It establishes *specifications* for standards of metals and alloys and determines their metallurgical constants and properties. It conducts investigations looking to the improvement of metallurgical processes, such as annealing, tempering, casting, and welding. It designs and constructs apparatus for metallurgical purposes. The

division is equipped for all sorts of metallurgical investigations, including microscopic and thermal analysis, heat treatment, the working of metals, and foundry operations.

**9. Clay and Silicate Products Division.**

The clay and silicate products division makes investigations in the principles involved in the manufacture of clay and silicate products, including pottery, tiles, porcelain, glass, cement, lime, gypsum, stone, refractories, and the enameling of metals. It determines the formulas and *specifications* for standard qualities of such materials. It makes tests of clay, glass, enamels, refractories, cements, and plasters. It studies manufacturing processes, with the purpose of improving quality and eliminating waste. The division has complete equipment for the experimental manufacture of cement, optical glass, and pottery.

**Commercial Standards Group.**

The function of this group is to aid the various industries to *standardize*, as far as practicable, the types, sizes, and qualities, of the commodities which they produce for market, and the nomenclature applicable there-to, in order to reduce, or eliminate, the wastes which result from excessive variety. The group acts as a neutral and friendly meeting ground for the various groups in each industry, and is able to bring into conference *producers*, *distributors*, and *consumers*, for the purpose of surveying the existing diversity of production and nomenclature, analyzing the demand, and developing and adopting a program which will concentrate production, sale, and use on those types, sizes, and qualities which are of greatest usefulness and practicability. Future development is safe-guarded by the establishment of standing committees in each industry for the

periodical reconsideration of the program initially adopted.

The division of building and housing of this group endeavors to reduce costs by encouraging the use of standard sizes of building materials and by simplifying construction practice. Its activities also include the development of uniform building codes, a survey of the economics and statistics of construction with a view to the elimination of periodical peaks and depressions, the investigation of financing, and a study of municipal zoning. Standard provisions for municipal building and plumbing codes have been prepared in cooperation with leading architects, municipal engineers, fire underwriters, builders, and others. In the preparation of these codes, extensive tests of materials were conducted at the Bureau's laboratories, and preliminary drafts of the codes were submitted to hundreds of engineers, architects, and public officials for criticism. The resulting provisions are being used by many municipalities, with appreciable savings in building costs.

Municipal zoning is of fundamental importance in the elimination of waste in housing. The continuous rebuilding of different sections of towns and cities as they change from residential to business districts is, to a very large extent, an avoidable waste. To aid in remedying this situation a standard zoning enabling act drafted under the auspices of the division of building and housing is being used by nineteen states.

**Other National Standardizing Laboratories.**

In addition to the research, technical, and standardizing laboratories of Austria, England, France, Germany, and the United States, above mentioned, there are national standardizing institutions in Argentina, Australia, Belgium, Canada, Italy, Japan, Jugoslavia, Poland,

Portugal, Roumania, Spain, Switzerland, Turkey, and several other countries.

These institutions have made notable advancements in science and in the application of precision methods to industry.

## CHAPTER IX

## TREND OF STANDARDIZATION

Standardization is the outstanding note of the industry of this century. It ramifies to the remotest details of our industrial regime, and its trends are highly significant; they tap all sources of scientific knowledge and affect every phase of design, production, and utilization.

The trend is definitely away from mere *opinion,* or even *expert judgment,* and toward those qualities or characteristics of a commodity, verifiable by *measurement,* which assure maximum utility. This affects quality at its source, not only in the material, but in the design of the product, and in the process by which it is fabricated.

The trend is away from mere duplication of material once found acceptable, away from mere *brand* designation, still further away from mere description or qualitative prescription. The trend is toward a precise statement, in measurable terms, of the magnitudes of the pertinent dimensions or characteristics which determine the utility. Furthermore, the trend is definitely toward the *work value* or *utility factor* method of expressing numerically the performance requirements in specifications.

The trend is toward a minimum number of standards of quality, perhaps a single national, or even international standard, for each service to be rendered, each need to be met. With precise methods of arriving at the data comes the natural unification of specifications, the reduction in their number as they approach ideal measures of the quality desired, as made possible by science and service,

and as the size of the groups interested in a given specification increases.

The trend is toward making *standardization* an active principle in organization and administration in every country and in every field. This is evidenced by the multiplication of national standardizing agencies in all of the important countries of the world, as well as the formation of technical committees on standardization in the great national engineering, technical, and scientific societies. Standardization is rapidly becoming a primary aspect of all well-ordered activities rather than an incidental activity supplemental to others.

The standardization procedure itself is gradually becoming standardized. Principles of practice are gradually being established as to the initiation, sponsorship, participation, technical basis for requirements, form, criticism, revision, adoption, jurisdiction, promulgation, and adherence. As the scientific basis for such procedure becomes more convincing, acceptance by wider jurisdictions becomes relatively easier and standardization is accelerated on a broader basis of acceptance.

The boundaries of the standardization field are expanding and the prospect is that it will soon cover, systematically, all science and industry, securing the full cooperation of all concerned, focussing every pertinent knowledge on each item standardized, feeding back service experience to the standardizing agencies, and adopting the presumptively most feasible requirements, all things considered, thus making a general standard.

Standardization is universal in modern industry. The entire output of industry, as well as the *materials*, *machines*, *procedures*, and *processes*, are being standardized, some by individuals or firms, others by technical organizations, still others by the users. Many are being standardized by governments for their own use.

There is almost no limit to the standardization of the processes and products of mass production, and the benefits to be secured from the perfected service of well-standardized products are immeasurable. Most of all, standardization has become recognized not as a stage to be completed but as a *continuing process*, literally a systematic harvesting of experience and discovery used in perfecting industry. The United States Government program of standardization of quality through specifications, for example, must eventually include at least all articles and services used in large quantities by the government. The trend is to cooperate for the broadest jurisdictions, and this points toward national standards assuring the best feasible products for the nation.

**Recent Activity in Standardization.**

There is everywhere intense activity in standardization through older organizations and through newer agencies, both national and international. Nor is such activity limited to the industrial field. In science, terminology, methods, instruments, and constants are being standardized for ease, speed of diffusion of data, and to secure comparable results. In medical research and practice, measured procedure is increasing in diagnosis and treatment. The trend is notable; the struggle for standards based on new experience and new knowledge winning through merit. Always the chaotic, chance qualities and sizes give way to orderly, efficient types, qualities, and sizes, just as evolution results in the development of standard types of life forms adapted to a given environment. Even the fine arts bear the impress of standards—the metrics of verse, the rhythm of ornament and motion, and the proportions of structures. The interplay of standards is seen in unsuspected fields where their rôle is mandatory—sometimes with a rigor superior to legal enactment.

**Development of Standards of Quantity and Quality.**

During the past quarter of a century, the varieties and precision of measurement have multiplied manyfold. Each requires units, standards, and methods of measurement. Their variety grows and will continue to grow rapidly, for every aspect of matter and energy calls for a type of measurement with characteristic problems, and becomes material for *standardization*. Our mastery of nature depends on such measurements. Today, wave lengths of light may be measured to within four trillionths of an inch and mass may be measured to one part in a hundred million. Scales may be ruled accurately to one-millionth of an inch. Not only so, but the measurable ranges of each kind of measurement have been extended, incredibly, to infinitesimals—the diameters of atomic nuclei, and to distances of ten or more million light-years.

With the rapid growth of measurements, their varieties, ranges, and precision, it is now possible to measure quality or fitness for use, performance or utility of devices, practice or effectiveness of processes. These call for standards of quality, performance, or practice, stating in measurable terms the pertinent magnitudes which determine net utility. These standards of quality are called *specifications*. As they approach definiteness through precise measures they become service standards. Their full scope covers all of industry when scientifically ordered, for measures must guide every step, every factor, in making or doing things to ensure their utmost utility.

When a federal, state, or municipal government, or a large corporation, buys commodities, the large quantities involved forbid risk of *poor quality*. The demand must not be impracticable or uncommercial; hence to secure a product producible in industry and usable in service, all concerned must be consulted—*maker*, *vendor*, *buyer*, *user*. A typical case of this was in formulating the Federal

specification for electric lamps in 1907. This was drafted in conference with Government lighting experts, lamp buyers, representatives of makers and vendors, and experts in photometry. The great variety of lamps then in use was promptly simplified to a moderate number adequate for all needs. The specification has been revised nine times as progress in the art of manufacture and the needs of the user have made changes desirable, with the joint approval of all. Its provisions are feasible industrial practice, and the lamps are inspected at the manufacturer's works to minimize cost and delay. Lamps accepted under the specifications serve their purpose effectively. Today the government specifications for incandescent lamps apply to the entire American public, largely because all concerned are parties to their formulation and revision. A similar story might be told of many other commodities.

While *service* is the ultimate test of *fitness*, production must precede service. The designer and the producer must use the skill and data at hand, for the buyer is waiting in the market. As a basis for purchase, sale, and use, standards are drafted with all degrees of thoroughness—*liberally* at first, *more definitely* as increase in knowledge permits. The cycle begins empirically. The experts draft a tentative specification in such terms as the manufacturer may be able to apply to making the product. As the user must pay for the product, his voice must be heeded, but the user is less concerned with the details of the measurements which assure such quality than with the *net utility* of the product.

**Relation of Research to Standards and Standardization.**

Scientific research finds its natural outlet in *standard data, standard materials, standard processes, or standard devices;* conversely, standardization finds in research its greatest contributor, yielding new and often incredible

efficiencies. The rule-of-thumb method is superseded by scientific experimental research, every conclusion of which must meet the challenge of repetition and ability for verification. This method is by no means ineffective; it implies personal judgment often based on long experience, skill, and careful thought. It can not be scientific or permanent, for personal judgments differ, and only experiment reproducible anywhere can afford a convincing basis for final acceptance. Science allows personal judgment in *planning research* but aims to balance or eliminate bias, or the purely personal opinion, in the *applied result.*

Research is the vital factor in standardization, chiefly through seven lines of approach: (1) measuring the need to be met; (2) analysis of the factors adapted to meet the need; (3) fixing measured controls for producing specified quality; (4) basing such controls on correlation of fitness factors with service utility; (5) devising methods of test of quality for the producer and for the consumer; (6) analysis of service experience or simulated service to aid in improving the standard; (7) and most important of all research fundamental to the pure sciences involved.

The measures of the need are the matrix for the specification. Point by point the measured quality must match the known need. The measure of the need is basic. Modern science is making it possible not only to measure every need, but to create new desires and needs for the enrichment of life. Fitness for use is the proper criterion of quality, and fitness can be assured only when the need to be met is scientifically measured. Such measures are the basis for all standardization.

Research studies the factors effective in a given product, and the vast literature of science contains the numerical or standard data and constants concerning the properties of materials, their control and application,

and these data are ready to be selected and applied to the desired use.

The design of a *product* is strictly comparable to the design of a *structure*. Properties are assembled whose magnitudes correspond to the sizes of the parts of the structure. The net service is a resultant. The product is given the best dimensions and best magnitudes ascertainable and these are modified as required for use and reasonable cost in mass production.

Research thus affects every phase of the choice, treatment, and use of *materials* and *energy*, specifically through the discovery of correlations of the properties of matter and energy with useful service to man. In commerce, the properties of commodities are, of course, the real utilities sold, bought, and used. The *utility* of things depends upon the nature, magnitude, and constancy of these properties. The purpose of research is to determine these properties, and to correlate them with their uses is its main problem. By eliminating the useless or harmful properties and developing the useful properties, the net serviceability is enhanced.

Process standards are the means by which research is applied to the production of serviceable things. There is a best standard humidity for cotton spinning; a best compression ratio in the internal-combustion motor; a best volatility curve for a gasoline; a best diameter for a conductor for a given current, to avoid overheating and undue cost of metal. These are matters of *standardization*. They are its principal task. They cannot be fixed by service experience alone for the ideal value may not, usually does not, occur in experience. It occurs as a matter of course in experimental research which measures the effect of each factor and finds by experiment the maximum, minimum, and optimum magnitudes. Research is an *appeal to the nature of things*, and its findings must, through standardization, enter into the control of the

processes of industry to serve man. Numerical constants which express the behavior of matter and energy are unlimited in number, they inhere in the nature of things, and their accuracy is their sole merit. They are indispensable in planning the processes of science and industry and become a permanent service element in industry, playing their part no less than the tool or the power. Dimensions are important, but the measure of *properties* is now quite as important and exacting as control of size, and far more productive of new and superior kinds of service.

Research has a field in devising tests which may be regarded as a temporary expedient until the standardized process makes the quality inevitable and never failing. Then, with all factors of the productive process standardized, the process will unfailingly deliver products of uniformly high quality and exact dimensions.

Service research, hitherto somewhat random, is becoming recognized as the true complement of laboratory research in completing the *standardization cycle.* Laboratory research discloses facts which service alone cannot reveal. It discovers faults in materials, defects in devices, imperfections in service, and finds their cause and cure. It does far more, for it lays down new principles which permit progress not only along old lines, but, by entirely new methods, creates new possibilities.

With active cooperation between *maker, vendor, buyer, user, and the research laboratory,* the specification becomes a means of steady progress in the industry concerned, and, combined with service experience, facilitates the more efficient adaptation of materials to their uses. Inflexible specifications or standards retard progress, but if allowed to grow apace with new service experience and research data, the specification becomes a distinct aid to such progress. Standardization in the nature of the case implies something of a practicable ideal. When

it ceases to be such as ideal it ceases to be true standardization and becomes simply fixation.

Standard industrial materials, processes and products, exist by thousands which owe their efficiency, even their existence, to scientific research. The distribution of power, the instantaneous communication possible everywhere, automotive speeds far beyond service demands of the general public, are literally creating a new era of service and enlightenment through standardization.

Research takes service experience, analyses it, and gives the data to the standardizing agencies, for use in revising the specification. Service integrates all factors determining *net utility*. Use is the dictator, hence the appeal to service is logical, since service only can tell the whole story and is, and should be, the *ultimate criterion of fitness*. Service experience yields far more than mere opinions of users. It is the scientific analysis of the service which is demanded, measured as carefully as we measure the parts of a machine. Hence *tire miles, car miles, miles per gallon, cents per mile, watts per candle,* and the like, are shop parlance where service efficiencies are in daily question. Service efficiencies must be measured and the data used in revision of the specification. Service experience, viewed in the light of the laboratory tests must, however, be the ultimate criterion for judging the adequacy of the specifications themselves, or the need for their improvement.

Research on the factors which add utility to products permits standardization to advance, and is gainful out of all proportion to its cost. Accuracy aids utility, for example, since accurate products with proper allowance for fit, assemble more easily, function more effectively, and wear longer. It is difficult to estimate the total gain from a high degree of accuracy even of such products as nuts and bolts when standardized and simplified to staple standard sizes. The piston of Watt's first steam

engine fitted the cylinder to within about the thickness of a coin. Today, internal-combustion motors are made in which the cylinder is true to dimension to within one twenty-five-hundredth of an inch.

Necessary close dimensional limits or tolerances should be set intelligently. On the other hand, non-functioning dimensions should be allowed more tolerance for economy of production. Experts realize that the setting of tolerances calls for research and experiment. The ideal is to work as close to optimum measurements as feasible. In economical manufacturing practice, products are usually made just accurate enough to serve their purpose and no more, as *unnecessary refinement* of fit causes unnecessary cost in production, which is always passed along to the ultimate user.

More and more through research the most effective dimensions and measures are applied to materials and devices. The standards of control in measurements are less and less subject to opinion or even expert judgment. Experts themselves recognize that the day of *arbitrary opinion* is passing, that experimental research and service experience can best guide every item of the standard. With great gaps in our precise knowledge of energy and the properties of matter, empiricism still rules in many individual cases, but its domain narrows as research gives us measured data based on scientific methods.

Standards of quality replace guesswork, and are now specified in measurable terms by which the product may be made and tested. The factors in making a thing are today measured to insure the standard utility, but the user is becoming equally exact in fitting the precise needed quality to the desired use through measurement. Such research does far more than furnish a scientific basis for fair dealing; it steadily perfects the service which industry renders the individual, the ultimate consumer, for whom all industry exists.

Our present industrial wastes in production and distribution are largely caused by a lack of understanding, by both producers and consumers, of the benefits that accrue from an intelligent application of the *principles of standardization*. Our industries have multiplied so rapidly both in number and kind that the brunt of effort has been spent in satisfying the immediate demands for expansion as they arise, without giving adequate consideration, in most cases, to the possibilities of concerted action looking to standardization of materials, type, design and dimensions of products, and to practice, and performance in service.

The present, however, is a period of transformation and improvement in this respect, which may be called a *renaissance* of the standardization ideal and practice; and this period is further characterized by a growing realization by the leaders of industry of the economic advantages to be gained from the elimination of these preventable wastes which are such a severe drain on our resources. It is a reflection on the engineering profession that it has allowed the existing situation to develop to the present state of confusion, but it is one of the encouraging signs of the times that the profession is now awake to its responsibilities and is making masterful efforts to bring order and economy out of the existing chaos and waste.

No standardization is final, since science and experience are always advancing and more effective equipment and methods are steadily being introduced into industry. The specification should be improved by steps not too frequent to unduly interrupt the course of industry and trade, but often enough not to lose the great gains from prompt use of new knowledge. Its aim is not fixity or stagnation, but to add serviceability as often as the potential gain makes it worthwhile.

**Trend in Quality Standards.**

There is a general upward trend in quality standards, amounting nearly to an unformulated law of economics. When production exceeds consumption, competition tends to elevate the standard. Under such conditions the purchaser demands the better article. The movement toward higher quality is counterbalanced by periods when consumption is greater than production, and competition tends to lower the quality level. These cycles recur according to the laws of economics.

The upward trend is toward higher standards, and greater refinement of limiting variations from standard. For example, the automotive industry has never produced so great an output as in recent years, yet quality has advanced and costs have decreased.

**A Look into the Future.**

Prediction is always hazardous, but, according to Edward A. Filene, the eminent business executive, it is believed that the signs of the times indicate that we are on the eve of changes in business and industry that will be so far-reaching that the historian of the future will refer to them as the *second great industrial or economic revolution.*

The coming inevitable conditions will drive American business and industry into mass production and mass distribution as never before. This mass principle, wisely applied, will result in hitherto undreamed-of *economies* and *efficiencies,* compelled by the struggle of sharp competition, which will result in a marked reduction in prices. The main financial idea of mass production and mass distribution is that the largest total is to be made from the sale of the greatest number of like articles at a small profit per unit. The present excess manufacturing capacity of industry will be one of the principal causes of this supercompetitive era.

This second industrial revolution will be led by chemists, physicists, engineers, economists and administrators. In fact, the business man of tomorrow must have the *technical mind* and be guided by *economic principles.*

The coming changes in business and industry will be a more extensive and intensive application of the principles of machine power, specialization and large-scale production than that which produced the Industrial Revolution of 1770–1840.

The wastes of low production will be reduced or eliminated by exercising a more scientific control of materials. The utilization of raw materials will be studied more closely; more accurate standards of manufacturing that will guard against the unwise and wasteful use of basic materials will be worked out; and materials will be bought more scientifically and less speculatively.

Mass production will mean, of necessity, an increasing mechanization of the processes of production and an increasing standardization of products. The coming industrial or economic revolution and *intensive war on waste* will be due to the fact that business is not being done on a really scientific basis; this war on waste will demand a thorough overhauling of our economic, financial, managerial, and operating principles and practices, a warfare in which the *manufacturer,* the *merchant,* and the *banker* must join.

# APPENDIX

## STANDARDIZATION AND COORDINATION OF GOVERNMENT PURCHASES

The United States Government is the largest purchaser of materials and supplies in the world, both as to quantity and variety. The annual purchases amount to from $250,000,000 to $300,000,000. This fact is not generally realized by the public. The range of variety of items included in these purchases extends from provisions to pig iron and from hosiery to hardware. Under the new *budget system* it has been recognized that when the Government goes into the market it must have suitable *quality standards* on which to base its purchases.

With the passage of the *Budget and Accounting Act* and the installation of the *Bureau of the Budget* in 1921, the President of the United States became, for the first time in the history of this country, the actual business head of the Federal Government. One of the principal questions before him was the necessity of setting up certain agencies for the coordination and control of government routine business. To promote economy and efficiency in this routine business, the President designated a *Chief Coordinator* who is charged with the formulation and application of uniform business principles and methods. He acts under the supervision of the *Director of the Bureau of the Budget.*

The budget in business is a plan for coordinating and directing all of the forces of that business toward the attainment of a definite objective. This objective, in the case of the government, as in any other business, is economy and efficiency in the operation of the business.

The national budget is simply the ordinary, every-day common sense of successful big business applied to the routine business of the United States Government—the biggest business in the world.

By direction of the President, there were established several Federal coordinating boards relating to certain specific activities of the government. Those directly concerned with the standardization of purchases and purchasing methods and procedures, are as follows: *Federal Specifications Board, Interdepartmental Board of Contracts and Adjustments*, and the *Federal Purchasing Board*. The titles of these boards indicate the activities with which they are concerned. They form an integral part of the National Budget System and are independent of any executive department or independent establishment. They are responsible only to the Chief Coordinator.

There is a general aversion to Government boards. Some wag has defined a board as " . . . something that is long, narrow, and wooden, and likely to be warped." This definition cannot fairly be applied to these coordinating boards.

**Organization and Procedure of the Federal Specifications Board.**

This Board is composed of representatives from departments and independent establishments purchasing materials or services in accordance with specifications prepared in such department. The Board was created by executive order promulgated in *Bureau of the Budget Circular* 42 of Oct. 10, 1921, for purposes of coordination and economy in the procurement of products and services used by the Government under specifications prepared in the various branches thereof. It compiles and adopts standard specifications for products and services and brings specifications into harmony with the best commer-

cial practice wherever the conditions permit. It standardizes nomenclature, dimensions to insure ready interchangeability of supplies and interworking of parts made by different manufacturers, and limits the number of types, grades and sizes, of manufactured products used by the Government.

The initial meeting of the board was held on Oct. 31, 1921, at which time an executive committee, consisting of representatives from the ten executive departments, The Panama Canal, and the General Supply Committee, was formed, as being more compact for the routine handling of the business of the board. A representative of the Merchant Fleet Corporation has since been added.

The procedure adopted for the consideration of specifications is as follows: The need of a specification for a given article or material, for either technical or business reasons, is fully considered by the executive committee and the subject is then referred to a technical committee composed of the Government experts in the particular subject, for consideration of all existing government and commercial specifications.

These technical committees have been formed in recognition of the fact that, generally, the opinion of a small group of qualified individuals is better than the opinion of any one expert, and differences of opinion can best be eliminated in informal conferences.

In the government service there is the greatest aggregation of technical and scientific talent to be found in this country, covering every branch of knowledge, and the best of this talent is utilized in the personnel of the various technical committees. Qualified officers and civilians from the War Department, Navy Department, and Marine Corps work with scientific and technical civilians from the Bureau of Standards, Bureau of Mines, Bureau of Chemistry and Soils, and other scientific and technical bureaus of the Government.

A specification is selected, or written, by the technical committee concerned, which will be suitable for the uses of all departments and independent establishments of the government. The cooperation and advice of interested commercial and industrial concerns is requested, and their recommendations are fully considered by the technical committee. The specification as agreed upon by the technical committee is then recommended to the executive committee of the board, and by it is submitted to all departments and establishments of the government, through their respective representatives on the Federal Specifications Board for comment and criticism. At the same time, copies of the proposed specifications are submitted to the American Engineering Standards Committee, with a request for their informal assistance in securing comment and criticism from the various interested engineering and technical societies and industries of the country. Copies are also sent to representative trade journals. All criticisms received are referred back to the respective technical committees for consideration on their merits. When the specification is finally agreed upon, it is promulgated by the Federal Specifications Board as official United States Government Master Specification for use in connection with the purchase of the commodity covered by the specification.

**Extent of Board's Authority.**

The master specifications promulgated by the board cover technical details only. The individual specifications published by the several departments and independent establishments and based upon these master specifications, include such additional non-technical information as may be desired, provided it does not amend or conflict with the technical details of the master specification.

The circular establishing the Federal Specifications Board states that " . . . the specifications adopted

and promulgated by the Board shall be binding upon and govern all departments and independent establishments of the Federal Government . . . ," and was issued by the Director of the Bureau of the Budget, by direction of the President.

The Federal Specifications Board has one great advantage over other standardizing bodies in the United States in that the Standard specifications officially promulgated are required by Executive authority to be used by all departments and establishments of the Federal Government.

At present, the Federal Specifications Board is directing its attention to *commercial commodities*, and is not considering materials and devices of a strictly military nature, such as ordnance material, ammunition and explosives, military aeronautics, chemical warfare, general military equipment, materials used in connection with the construction of naval vessels, etc.

**Economy of Using Standardized Purchase Specifications.**

The preparation and use of master commodity specifications for the entire Federal Government is an essential step in the economy which results from the purchase of materials and supplies in large quantities. In no field of government operation was there greater need of constructive work than in the field of purchase standards. For certain classes of materials and supplies, there were almost as many variations in the department's specifications for a given article as there were specification writers. These specifications were developed through the years, and bore the impress of notions and whims of individuals who were unfamiliar with commercial conditions. The peculiar requirements of certain of these specifications meant departure from commercial practice, necessitating special fabrication, which always involves greater cost. The Government has paid large sums of money for this lack of standardization.

Further details concerning the work of the Federal Specifications Board will be given later.

**Interdepartmental Board of Contracts and Adjustments.**

This board is composed of representatives from each department and independent establishments authorized by law to enter into important contracts. It was created by Executive order promulgated in *Bureau of the Budget Circular* 47 of Nov. 22, 1921, for the purpose of standardizing contract forms, securing the adoption of uniform policies as regards construction work, and uniform practices of interpretation and negotiation both preceding and following the actual execution of such contracts. It standardizes, where possible, the forms and methods of contract letting to the end that a uniform policy may control the making of contracts, with a view to such changes in form of contracts as will tend to enlist the interest of the contractor in behalf of economy and promptness of execution, as well as to eliminate those uncertainties of construction and hazards to be assumed by the contractor which have operated to increase the cost of government work and products; recommends general policies in the settlement of outstanding obligations arising from contracts of the United States; acts in an advisory capacity, when requested, to review and revise important contracts and agreements, to advise as to proper interpretation of contracts in process of execution, and to assist in the negotiation of important contracts and agreements relating to personal services, supplies, or construction work.

**Contracts Standardized.**

The vast sums expended by the Government for products and construction are expended largely under contract; before the establishment of the Bureau of the Budget, however, no coordination existed between the contracting agencies of the various departments and

independent establishments, and no coordination in many cases between branches of the same department; each department had its own forms and methods. The government had no standard forms of contract, no law prescribing the language of the contract, and no unified agency to tell what language should be used. Some of the larger departments had different forms and different methods in their several bureaus. There were 396 separate forms of contracts and leases, and 224 Federal Statutes with which to conform.

It is impossible to estimate the great waste that resulted from this condition of affairs, and the first great work of coordination was a revision and standardization of the government's contracting activities.

Several standard government forms have been adopted. Six forms were officially promulgated by *Bureau of the Budget Circular* 197, on Nov. 19, 1926, as follows:

Standard government form of invitation for bids, construction contract. (Standard Form 20.)

Standard government form of bid, construction contract. (Standard Form 21.)

Standard government instruction to bidders, construction and supplies. (Standard Form 22.)

Standard government form of contract, construction. (Standard Form 23.)

Standard government form of bid bond, construction or supplies. (Standard Form 24.)

Standard government form of performance bond, construction or supplies. (Standard Form 25.)

The departments and establishments of the government were directed by this circular to use these forms on and after Jan. 1, 1927, in connection with every formal contract for the construction or repair of public buildings or works, and if it should be considered necessary to deviate from these forms they were required to submit the proposed deviation to this board for consideration

and recommendation to the Director of the Bureau of the Budget for his approval.

Standard Forms 22, 24, and 25 were so drafted that they could be used in connection with the following standard government forms, subsequently promulgated, in contracting for supplies:

Standard government form of invitation for bids. (Standard Form 30.)

Standard government form of bid. (Standard Form 31.)

Standard government form of contract. (Standard Form 32.)

Standard government short form contract. (Standard Form 33.)

Standard government form of annual bid bond. (Standard Form 34.)

Standard government form of annual performance bond. (Standard Form 35.)

Standard government form of continuation schedule for Standard Form 31 or 33, supplies. (Standard Form 36.)

**Federal Purchasing Board.**

This board is composed of one representative from each department and independent establishment having authority to purchase supplies. It was created by Executive order promulgated in *Bureau of the Budget Circular* 25 of Aug. 25, 1921, to enable the Chief Coordinator to perform the duties of coordinating purchases throughout the several departments and establishments. It formulates policies and plans to unite purchasing activities of the several departments and establishments and to bring about business methods calculated effectively to safeguard the interests of the Government, and at the same time promote the confidence of private business interests having dealings with the government. The board studies purchase operations with a view to determining the advisability of centralizing purchases

within departments, coordination among departments, utilization of surplus, and economies to be effected by combined purchases. Detailed studies are made of the requirements of the government, as a whole, both as to quantities and qualities, available sources, localities, seasons of supply, means of transportation and storage, and kindred conditions involving purchase.

The Federal Purchasing Board is a policy-forming board rather than an operating purchasing agency, and devotes its attention to purchasing problems common to all branches of the Federal Government. Its efforts has been to *coordinate* purchasing activities so as to secure maximum results from the government's great buying power, but, at the same time, to avoid interference with departmental responsibilities.

In the field of procurement, the government purchasing methods had almost run riot before the establishment of the Bureau of the Budget and the coordinating agencies. These activities have grown up under conditions unfavorable to interdepartmental coordination, and, for the most part, purchases within the departments themselves were, until recently, without central direction. There were in the Treasury Department 26 uncoordinated purchasing agencies; in the Department of Agriculture, 18; and so on through the entire Government service, with the notable exception of the Navy Department, where purchases were highly centralized. These various uncoordinated purchasing activities within the several departments are rapidly being correlated so that at the present time there is complete coordination in the Treasury Department, Department of Agriculture, Commerce Department, etc.

The Federal Purchasing Board has been reorganized recently, by the formation of standing committees, as follows:

**I. Committee on Operations:**

1. *Policies:* Plans; purchase principles; purchase laws and regulations—present and proposed; decisions; definitions.

2. *Operations:* Organization; procedure; personnel; equipment, office, supplies, and blank forms.

**II. Committee on Relations:**

1. *Related Activities:* Requirements; specifications; deliveries; inspections; storage; disbursements.

2. *Sources:* Mailing lists; eligibility of suppliers—present, proposed, and debarred.

**III. Committee on Commodities:**

1. *Commodities:* Procurement studies and assignment of purchase classifications; sub-committees on procurement groups.

2. *Market Conditions:* General, seasonal, and casual trends; procurement forecasts.

**IV. Committee on Services:**

1. *Transportation:* Passenger and freight—air, automotive, rail, and water.

2. *Services:* Communications; power and light; real estate; miscellaneous personal.

Several commodity sub-committees have been formed, as follows:

**Sub-committee I.**

A—Ammunition; F—Bombs, Mines, and Torpedoes; L—Cellulose Products; O—Chemicals; P—Cleaning Compounds; U—Drugs and Medicines; BB—Gases; TT—Paints and Paint Ingredients.

**Sub-committee II.**

B—Animal Products; N—Cereals and Provender; Y—Fruits and Vegetables; EE—Groceries; MM—Live Stock;

PP—Meats and Poultry; FFF—Tobacco Products; JJJ—Vegetable Products.

**Sub-committee III.**

C—Arms, Small; D—Artillery; E—Boilers and Tanks; S—Cooking and Heating Apparatus; X—Engines; GG—Instruments; OO—Machinery; WW—Pipe and Pipe Fittings; XX—Pumps and Pumping Machinery; GGG—Tools; HHH—Tubes and Tubing; KKK—Vehicles.

**Sub-committee IV.**

G—Books and Periodicals; H—Brooms and Brushes; KK—Leather and Leather Goods; UU—Paper Products; YY—Recreational Apparatus; SS—Rubber Goods; EEE—Toilet Articles and Supplies.

**Sub-committee V.**

J—Cable and Wire, Insulated; W—Electric Apparatus; CC—Generators and Motors; HH—Insulating Material.

**Sub-committee VI.**

K—Canvas Articles; T—Cordage; V—Dry Goods; JJ—Knitted Goods; LL—Lineoleum and Oil Cloth; BBB—Suits and Uniforms; CCC—Textiles; DDD—Textile Products.

**Sub-committee VII.**

M—Ceramics; AA—Furniture; DD—Glass and Glassware; FF—Hardware; NN—Lumber and Timber; RR—Metal Products; LLL—Woodenware.

**Sub-committee VIII.**

Q—Coal; R—Coal-tar Products; S—Fuel Oil; QQ—Metals; SS—Mineral Products; VV—Petroleum Products.

**Coordinator for Purchase.**

This office was established by Executive order promulgated in *Bureau of the Budget Circular* 160, May 29, 1925, to develop and coordinate the purchasing facilities of the Government. The coordinator for purchase is the agent through whom the Federal Purchasing Board, acting for and in behalf of the separate purchasing agencies of the Government, may, with the approval of the Chief Coordinator, effect such joint procurement arrangements as may be agreed upon. He personally, or through some department or establishment advantageously situated, issues single proposals inviting bids on individual commodities or natural groups thereof for the combined requirements of two or more departments or establishments, as recommended after study by the Federal Purchasing Board. He also performs such additional duties in the clearance and distribution of procurement information and operations incident thereto as may be delegated to him by the Chief Coordinator.

**Inspection.**

Consideration is being given in the Government service to the methods of *inspection of material* at time of delivery, as it is realized that the best possible purchasing organization can not produce good results if the material delivered is not in accordance with the specifications, and the only way to check this is by inspection. The government, through its several departments, maintains a diversified inspection service scattered throughout the country. It is planned to give a flexibility to this service that will make it generally available whenever required.

**Coordination of Purchase Activities.**

The magnitude of the annual purchases made by the government emphasized the need of coordination. This

coordination involved the activities of three of the most important Government coordinating boards—The Federal Specifications Board, Interdepartmental Board of Contracts and Adjustment, and the Federal Purchasing Board. *Efficient procurement* called for the uniform application of *approved methods of purchasing* to all agencies of the government. These approved methods required *standardized specifications* and *standardized contracts.*

**Standard Form for Specifications.**

The Federal Specifications Board has adopted a *Standard Form* to be followed by all of its technical committees in drafting specifications, as far as it may be applicable. The form is as follows:

All specifications shall be written on 8- by 10½-inch paper.

All specifications shall be given a consecutive number. Successive revisions of a given specification shall be indicated by adding *a* to the number for the first revision, *b* for the second revision, etc.

All specifications shall, as far as practicable, be arranged in eight sections as described below. In case a given specification does not include requirements or information which come within the scope of one of the sections, a statement to that effect shall be made under the heading of that section. For example, if nothing is to be specified under General Requirements, the caption General Requirements, together with the numeral IV, shall appear, with the statement "There are no general requirements applicable to this specification."

In case it is desired to make paragraph or subparagraph subdivisions under a given section, the successive paragraph and subparagraph designations shall be as follows:

I. Section Heading
1. Paragraph Heading
(*a*) Subparagraph Heading
(1) Sub-subparagraph Heading

If the specification includes tables or figures, use Arabic numerals in reference thereto.

(STANDARD FORM)

UNITED STATES GOVERNMENT
PROPOSED
MASTER SPECIFICATION
FOR
NAME OF ARTICLE OR MATERIAL

(The first draft of the specification, as submitted to the board by the technical committee for circulation to the Government departments and establishments for comment and criticism, shall bear the above caption. The final draft of the specification, as submitted to the board by the technical committee, after consideration of the comments and criticisms received, shall be as above with the word *proposed* deleted.)

I. GENERAL SPECIFICATIONS.

In this section reference should be made to any applicable general specification and drawings forming a part of the specification, with a statement that such general specification and drawings form a part of the specification. This section serves as an index to the documents which must be considered to permit a complete interpretation of the specification.

II. TYPES, GRADES, CLASSES, ETC. (as applicable).

In this section should be listed the several types, grades, classes, etc., of articles or materials covered by the specification, preceded by the words: ". . . shall be of the following types (grades, classes, etc.)." If only one type, grade, class, etc. is required, it should be so stated. The types, grades, classes, etc. (if more than one) should be listed under a brief name convenient for reference and in accordance with commercial practice, and, whenever practicable, should be designated by capital letters or arabic numerals. The same designations should be used under Detail Requirements, Section V, and

under Methods of Inspection and Tests, Etc., Section VI, if applicable, so that Section II will serve as an index to the subject matter of the specification.

### III. MATERIAL AND WORKMANSHIP, ETC.

Under this heading should be included any necessary requirements relative to the character or quality of the materials used, the method of manufacture, and workmanship. Any requirements with reference to the use of scrap should be here stated.

### IV. GENERAL REQUIREMENTS.

All essential requirements and descriptions which are applicable to the articles or materials and which are common to all of the types, grades, classes, etc., covered by the specifications, should be stated in this section. Tolerances permitted, if common to all types, grades, classes, etc. should be included. If spare parts are required for all types, grades, classes, etc. they should be here stated.

### V. DETAIL REQUIREMENTS.

In this section the items listed in Section II, Types, Grades, Classes, Etc., should be considered consecutively, when practicable, using the name and designation in full, detailing for each, such physical and chemical requirements, characteristics, and descriptions as may be necessary to define clearly the articles or materials required. Where but one type, grade, or class, etc. is provided, care should be exercised to place detail requirements under this section rather than under Section IV. The following, when applicable, should be included, the statements under each heading being contained in a separate subparagraph, properly designated; Physical Requirements; Chemical Requirements; Treatment; Finish; Plans; Tolerances; Spare Parts not listed in Section IV.

### VI. METHOD OF INSPECTION, TESTS, ETC.

In this section should be stated the tests to which the articles or materials are to be subjected in order to determine whether they conform to the requirements of the specification. This section should also include such descriptions of tests and methods of analysis as may be necessary to insure that they will be properly conducted, and other information, such as location of test specimens, method of sampling for chemical analysis, etc.

When an umpire method of analysis is specified, either in the form of a detailed description or by reference to some accepted standard

method, it should be placed at the end of this section and be plainly captioned Umpire Method of Analysis.

VII. PACKING AND MARKING.

Ordinarily, instructions regarding packing and marking do not form a part of the master specifications promulgated by the Federal Specifications Board. Instances will arise, however, where marking for identification, or certification, and special methods of packing to insure against damage in shipment, etc. should properly be included. Where packing or marking, or both, are included in the specification, detailed instructions therefor should appear in this section.

VIII. NOTES.

This section should be restricted to informative matter only, and should contain all necessary information of a general or explanatory nature, which is not properly a part of the preceding sections. For example, when it is desirable to state the use for which the material or article is suitable, such statement should appear in this section. It is appropriate to make reference here to other specifications covering other types, grades, classes, etc., of the same or similar material or article. Citations to specifications followed without change of technical requirements or with slight deviations, should appear here.

(Sample Specification drafted in conformity with Standard Form of the Federal Government.)

**Cover Sheet of Specification.**

UNITED STATES GOVERNMENT
MASTER SPECIFICATION
FOR
BLADES, HACK SAW
FEDERAL SPECIFICATIONS BOARD
SPECIFICATION NO. 415

This specification includes the following items:

Hand-frame Blades, All Hard; Hand-frame Blades, Soft Back; and Machine Blades, All Hard.

This specification was officially promulgated by the Federal Specifications Board on July 9, 1926, for the use of the Departments and Independent Establishments of the Government in the purchase of Hack-saw Blades.

The latest date on which the technical requirements of this specification shall become mandatory for all Departments and Independent Establishments of the Government, is Oct. 9, 1926. They may be put into effect however, at any earlier date, after promulgation.

## Text of Specification.

UNITED STATES GOVERNMENT
MASTER SPECIFICATION
FOR
BLADES, HACK SAW

### I. GENERAL SPECIFICATIONS.

There are no general specifications applicable to this specification.

### II. TYPES.

Hack-saw blades shall be of the following types:

*A*. Hand-frame blades, all hard.
*B*. Hand-frame blades, soft back.
*C*. Machine blades, all hard.

### III. MATERIAL AND WORKMANSHIP.

Hack-saw blades shall be made of high-grade material and free from all defects affecting their appearance or serviceability. They shall be of high-grade workmanship and made in accordance with the best commercial practice.

### IV. GENERAL REQUIREMENTS.

The teeth shall be cut, evenly spaced, of uniform height, and properly set. The maximum set shall be not greater than is necessary for free, smooth, and rapid cutting. The length of blades shall be the distance from center to center of holes. The ends of all blades shall not be hardened in order to prevent holes from pulling out when the saw is in tension between holders. Each hack-saw blade shall be stamped or otherwise permanently marked with the maker's name, brand, or trade mark. The number of teeth per inch shall be as follows: regular, 14 teeth; fine, 24 teeth; tubing, 32 teeth.

### V. DETAIL REQUIREMENTS.

1. Hand-frame blades, all hard, type *A*. These blades shall be uniformly hardened throughout except the ends. They shall be made of carbon tool steel or alloy tool steel; a tolerance of $\frac{3}{16}$ inch

will be allowed in distance between holes in blades. These blades shall conform to the table of dimensions below:

HAND-FRAME BLADES, ALL HARD

| Length, inches | Width, inches, minimum | Thickness, inches | | Teeth per inch | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 8 | 7/16 | 0.024 | 0.026 | 14 | 18 |
| 10 | ½ | 0.024 | 0.026 | 14 | 18 |
| 10 | ½ | 0.024 | 0.026 | 22 | 24 |
| 12 | ½ | 0.024 | 0.026 | 14 | 18 |
| 12 | ½ | 0.024 | 0.026 | 22 | 24 |

2. Hand-frame blades, soft back, type *B*. These blades shall have soft backs and shall be hardened on the cutting edge. They shall be made of carbon tool steel or alloy tool steel. A tolerance of 3/16 inch will be allowed in distance between holes in blades. These blades shall conform to the table of dimensions below:

HAND-FRAME BLADES, SOFT BACK

| Length, inches | Width, inches, minimum | Thickness, inches | | Teeth per inch | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 8 | 7/16 | 0.024 | 0.026 | 14 | 18 |
| 8 | 7/16 | 0.024 | 0.026 | 30 | 32 |
| 10 | ½ | 0.024 | 0.026 | 14 | 18 |
| 10 | ½ | 0.024 | 0.026 | 30 | 32 |
| 12 | ½ | 0.024 | 0.026 | 14 | 18 |
| 12 | ½ | 0.024 | 0.026 | 30 | 32 |

NOTE.—Blades with soft centers, known as flexible blades, will be accepted under this type, provided they are otherwise in accordance with specifications.

3. Machine blades, all hard, type *C*. These blades shall be uniformly hardened throughout except the ends. They shall be made of alloy tool steel. A tolerance of ½ inch will be allowed in distance between holes in blades. These blades shall conform to the table of dimensions on the following page:

MACHINE BLADES, ALL HARD

| Length, inches | Width, inches | Thickness, inches | | Teeth per inch | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum |
| 12 | 5/8 | 0.030 | 0.033 | 14 | 18 |
| 14 | 3/4 | 0.030 | 0.033 | 14 | 18 |
| 17 | 1 | 0.048 | 0.050 | 10 | 14 |

## VI. METHOD OF INSPECTION AND TEST.

1. Test. Selective tests as described herein will be conducted to determine the work values of hack-saw blades submitted by the various manufacturers. The results obtained in these tests will be entered on the lists of work values maintained by the department concerned. Separate lists will be maintained, respectively, of the average work values for types *A* and *B* carbon-steel hand-frames blades, the average work values for types *A* and *B* alloy-steel hand, frame blades, and the work values for type C alloy tool-steel machine blades. Each list will also contain the name of the manufacturer, brand name, and the type or types of hack-saw blades represented by the respective work values. Work-value tests will be conducted on the following representative types and sizes of carbon steel and alloy-steel hack-saw blades conforming to this specification.

| Kind | Type | Length, inches | Teeth per inch |
|---|---|---|---|
| Carbon and alloy | *A* | 12 | 14 to 18 |
| Carbon and alloy | *B* | 12 | 14 to 18 |
| Alloy (only) | *C* | 17 | 10 to 14 |

Selection of a suitable tooth size, within the limits specified, shall be made by the manufacturer, unless the number of teeth per inch is definitely specified by the Department concerned.

2. Hack-saw blades will be tested for the work values in machines operated under uniform conditions for respective types of blades, as follows:

| Type | Tension on blade in pounds | Maximum feed pressure during stroke in pounds | Strokes per minute |
|---|---|---|---|
| *A* and *B* | 275 | 12 | 60 |
| *C* | 550 | 60 | 60 |

The blades will be used to cut discs from a bar of annealed tool steel 3 inches in diameter, of a grade specified by the department concerned. Cutting shall be done without a lubricant.

3. Work values will be determined by testing three blades of each of the above types and sizes. Each blade will be tested to failure. Except when a blade is damaged accidentally, failure will be considered to have occurred when the blade cuts at an angle, cuts at an excessively slow rate, suffers breakage of body or teeth, or becomes otherwise unfit for useful service in the machine used for testing.

4. Records of the tests will contain data on the number of strokes required to cut off each disc from the bar and the number of discs removed by each blade before failure occurs.

5. The work value for any set of three blades of the same type and description will be computed from the test data, as follows:

| Blade number | Number of discs removed before failure | Average strokes per discs |
|---|---|---|
| 1 | *A* | *D* |
| 2 | *B* | *E* |
| 3 | *C* | *F* |

$$\frac{\text{Total number of strokes made by blade 1 before failure}}{A} = D$$

$$\frac{\text{Total number of strokes made by blade 2 before failure}}{B} = E$$

$$\frac{\text{Total number of strokes made by blade 3 before failure}}{C} = F$$

$$\frac{A + B + C}{3} = \text{Average discs per blade } G.$$

$$\frac{D + E + F}{3} = \text{General average strokes per disc } H.$$

$$\text{Work value} = \frac{G \times 10{,}000}{H}.$$

6. The method of averaging the work value of hand-frame blades types *A* and *B* is as follows:

$$\text{Average work value for hand frame} = \frac{\text{Work value, type } A + \text{work value type } B}{2}$$

7. Inspection.—From every four gross of blades under inspection or from the total number if less than four gross, blades of each type and size shall be selected at random for test. Blades having 18 teeth

per inch, or less, shall under conditions of the original test show a work value equal to that of blades of like description originally tested.

Hand-frame blades having more than 18 teeth per inch shall be tested as follows:

| Teeth per inch | Test |
|---|---|
| 22 to 24 | 6 cuts through commercial brass pipe, ¾-inch iron pipe size. |
| 30 to 32 | 6 cuts through commercial hard-drawn brass tubing, wall thickness 0.041 to 0.057 inch. |

Blades shall complete the six cuts without breakage of body or teeth.

If blades with 18 teeth or less fail under test to equal the original work value of blades of like description, or if 10 per cent of the number of sample blades with more than 18 teeth per inch, taken at random for test, fail to meet the tests specified, the entire shipment shall be rejected.

## VII. PACKING AND MARKING.

Hack-saw blades shall be packed and marked in accordance with standard commercial practice unless otherwise specified.

## VIII. NOTES.

1. Award of contract will be made to the bidder offering hack-saw blades having the highest selective factor and purchase of which it is considered would be to the best interest of the Department concerned. Selective factors for hand-frame blades will be based on the average work values for hand-frame blades and the average price per dozen quoted for the respective makes of hand-frame blades. Selective factors for machine blades will be based on the work value for machine blades and the average price per dozen quoted for the respective makes of machine blades. Selective factors are computed by dividing the work value attained by each manufacturer's product in tests described in Section VI hereunder by the average price per dozen as quoted in his bid.

2. The right is reserved to reject bids on brands of hack-saw blades which have not been subjected to the required tests and on those of which tests have been authorized but not completed by opening date of the bids. The attention of manufacturers is called to this requirement, and they are urged to forward as early as practicable

samples of hack-saw blades which they propose to offer to the department concerned in the future, in order that tests may be made.

These test will be conducted at the expense of the manufacturers. Information with reference to the expense involved and as to where the sample should be sent will be supplied upon application to the department of the government issuing the specifications and requisition. Hack-saw blades not marked in a permanent manner with the brand name, name or trade mark of the manufacturer will not be tested.

3. Hack-saw blades described in this specification are intended to cover the general needs of the Government. It is possible that other types and sizes may be needed from time to time. In such cases requisitions should state the reasons for requiring the other types and sizes and wherein the hack saw blades described in this specification will not be suitable.

## Technical Committees of the Federal Specification Board.

The Board now has 75 *technical committees* at work on the following groups of subjects; lubricants and liquid fuels; paints; oils; varnish and lumber; soap; rubber products; leather products; feeds and forage; refractories; electrical supplies; metals; builders hardware; hospital beds; fire-extinguishing liquid; sterilizing equipment; cordage; plumbing fixtures; textiles; wire rope and cable; bituminous roofing and waterproofing compounds; pipe, tubing, valves, fittings, etc.; linoleum and mastic flooring; heat-insulating materials; gaskets and packing materials; coal; brushes and brooms; hand fire extinguishers; fire-proof safes; paper; plate glass, window glass, glassware, chinaware, and stoneware; brick and building tile; provisions; plumbing fixtures for marine use; brake lining; cements, lime, and plaster; inks and typewriter ribbons; burglar-resisting safes; wood preservatives and methods of treatment; safety walkways for marine use; safety walkways for land use; road and paving materials; refrigerators; glue; telephones; abrasives and polishing materials; disinfectants; gauze and bandages; hand tools; machine screws, bolts, and

nuts; photographic supplies; drafting equipment and supplies; weighing and measuring devices; thermometers; spraying devices (horticultural); tableware and kitchen utensils; wearing apparel (non-military); insecticides; stitches, seams, and stitching; miscellaneous chemical products; hair for upholstery, mattresses, and pillows; safety goggles; radio apparatus; medical and surgical instruments, appliances, and supplies; gauges; tents and tent appliances; color; laundry equipment; foundry apparatus and supplies; caskets; wire screens; storage batteries; motor-propelled vehicles; and watchman's time systems.

**Cooperation in the Selection of Master Specifications.**

The selection of specifications, or purchase standards, by the consumer, without due regard to the manufacturing problems involved, would be as serious as the establishment of them by the manufacturers without a careful consideration of the needs of the consumer. In the selection of specifications for Government use, the Federal Specifications Board is coordinating these two interests in a manner which is fair to and understood by both manufacturer and user. Eventually all Government purchases will be based on correct standards of quality and practice.

Up to the present time (1928), 558 specifications have been promulgated as United States Government Master Specifications, covering all of the more important commodities, and their use by all of the departments, bureaus, and activities of the government is mandatory by Executive order.

The specifications promulgated by the Federal Specifications Board, as United States Government Master Specifications are listed in *Bureau of Standards Circular* 319, which is obtainable on application.

# BIBLIOGRAPHY


ALVORD, L. P., Editor, "Management's Handbook," The Ronald Press Co., 1924.

BIAGOSCH, HEINRICH, "Normung, Typung, Spezialisierung in der Papiermaschinen Industrie," Julius Springer, Berlin, 1924.

BIGOURDAN, G., "Le Système Métrique des Poids et Mesures," Gauthier-Villars, Paris, 1901.

BIRNBAUM, BRUNO, "Organization des Rationalisierung, Amerika-Deutschland," Reimer Hobbing, Berlin, 1927.

BOGART, ERNEST L. and CHARLES E. LANDON, "Modern Industry," Longmans, Green & Co., 1927.

BUCKINGHAM, EARLE, "Principles of Interchangeable Manufacture," Industrial Press, New York, 1921.

*Bureau of the Census, Monograph* III, "Integration of Industrial Operations."

*Bureau of the Census Monograph* IX, "The Growth of Industries."

*Bureau of Standards Circular* 1, "The National Bureau of Standards—Its Functions and Activities."

*Bureau of Standards Circular* 47, "Units of Weight and Measure."

*Bureau of Standards Circular* 60, "Electrical Units and Standards."

*Bureau of Standards Circular* 70, "Materials for the Household."

*Bureau of Standards Circular* 346, "Light Metals and Alloys."

*Bureau of Standards Scientific Paper* 436, "Interference Methods for Standardizing and Testing Precision Gauge Blocks."

*Bureau of Standards Circular* 535, "A Fundamental Basis for Measurements of Length."

*Bureau of Standards Miscellaneous Publication* 20, "Federal and State Laws Relating to Weights and Measures," 3rd Ed.

*Bureau of Standards Miscellaneous Publication* 64, "History of the Standard Weights and Measures of the United States."

*Bureau of Standards Handbook* 11, "Weights and Measures Administration."

*Bureau of Standards Yearbook*, 1927 and 1928.

*Bureau of Standards*, "A Primer of Simplified Practice."

*Bureau of Agricultural Economics*, Department of Agriculture, "National Standards for Farm Products."

CHANEY, H. J., "Our Weights and Measures," Eyre and Spottiswoode, London, 1897.

CHARPY, GEORGES, "Conditions et Essais de Réception des Métaux: Unification des Cahier des Charges," Dunod, Editeur, Paris, 1921.

CHISHOLM, CECIL, "Simplified Practice," Chapman & Hall, Ltd., London, 1927.

CHISHOLM, H. W., "On the Science of Weighing and Measuring," The Macmillan Co., 1877.

CLAPHAM, CHARLES B., "Metric System for Engineers," Chapman & Hall, Ltd., London, 1921.

*Deutscher Normenausschuss*, Berlin, "Die Deutsche Normung," 1927.

———, "Grundnormen," 1925.

———, "Die Dinormen," 1926.

DRURY, AUBREY, "World Metric Standardization—An Urgent Issue," World Metric Standardization Council, 681 Market St., San Francisco, Calif., 1922.

Encyclopedia Britannica, *Mass Production*, 13th Ed. Vol. 2, p. 821.

———, *Measurements*, 13th Ed. Vol. 2, p. 841.

———, *Weights and Measures*, 11th Ed. Vol. XXVIII, p. 477.

FARNHAM, DWIGHT T., "America *vs.* Europe in Industry," The Ronald Press Co., 1921.

FARNHAM, DWIGHT T. *et al*, "Profitable Science in Industry," The Macmillan Co., 1925.

FAUROTE, F. L. and H. C. ARNOLD, "Ford Methods and Ford Shops," Engineering Magazine Company, 1915.

Federated American Engineering Societies, "Waste in Industry," McGraw-Hill Book Company, Inc., 1921.

Filene, Edward A., "The Way Out," Doubleday Page & Co. 1925.

Garbotz, G., "Vereinheitlichung in der Industrie," R. Aldenberg, Munich and Berlin, 1920.

Gibson, A. H., "Natural Sources of Energy," G. P. Putnams Sons, 1913.

Glazebrook, Sir Richard, "Dictionary of Applied Physics," Vol. 3, p. 570, The Macmillan Co., 1923.

Guillaume, Charles Edward, "La Création du Bureau International des Poids et Mesures, et son Oeuvre," Gauthier-Villars, Paris, 1927.

———, "Unités et Étalons," Gauthier-Villars, Paris, 1893.

Hallock, William, and Herbert T. Wade, "The Evolution of Weights and Measures," The Macmillan Co., 1906.

Halsey, Frederick A., "The Metric Fallacy," 2nd Ed., The American Institute of Weights and Measures, 1920.

Hamilton, Douglas T., "Gages, Gaging, and Inspection," The Industrial Press, New York, 1918.

Harkness, William, "The Progress of Science as Exemplified in the Art of Weighing and Measuring," Smithsonian Report, 1888.

Harriman, N. F., "Principles of Scientific Purchasing," McGraw-Hill Book Company, Inc., 1928.

Kennelly, Arthur E., "Vestiges of Pre-metric Weights and Measures," The Macmillan Co., New York, 1928.

Kimball, Dexter S., "Principles of Industrial Organization," 3rd Ed., McGraw-Hill Book Company, Inc., 1925.

Kirby, Richard S., "The Elements of Specification Writing," 2nd Ed., John Wiley & Sons, Inc., 1921.

Lansburgh, Richard H., "Industrial Management," John Wiley & Sons, Inc., 1923.

Macgregor, D. H., "The Evolution of Industry," Henry Holt and Company, 1912.

Mantoux, Paul, "The Industrial Revolution in the Eighteenth Century." Revised edition translated from the French by Marjorie Vernon, Jonathan Cape, London, 1928.

MARSHALL, ALFRED, "Industry and Trade," 4th Ed., The Macmillan Co., 1923.

MARSHALL, L. C., "Industrial Society," The University of Chicago Press, 1918.

MEAD, D. W., "Contracts, Specifications and Engineering Relations," 2nd Ed., McGraw-Hill Book Company, Inc., 1924.

MEYERBERG, FREDERICK, "Über die Eingliederung der Normungsarbeit in die Organisation einer Maschinenfabrik," Julius Springer, 1924, Berlin.

National Industrial Conference Board, "The Metric *vs.* The English System of Weights and Measures," *Research Report* No. 42, The Century Co., New York, 1921.

National Research Council, E. W. WASHBURN, Editor-in-chief, "International Critical Tables" Washington, D. C., Vol. I, 1926; Vol. II, 1927; Vol. III, 1928; Vols. IV, V, and VI to follow.

OSTWALD, W., "Normungs-Grundsätze," Normenausschuss für das Graphische Gewerbe, Leipzig, 1922.

PERKIN, F. MOLLWO, "The Metric and British Systems of Weights, Measures and Coinage," Sir Isaac Pittman & Sons, Ltd., London, 1907.

PORSTMANN, W., "Normenlehre," A. Haase, Leipzig, 1917.

PORSTMANN, W., "Untersuchungen über Aufbau und Zusammenschluss der Masssysteme," Deutscher Normenausschuss, Berlin, 1920.

RADFORD, G. S., "The Control of Quality in Manufacture," The Ronald Press Co., 1922.

*Report* of Committee on Industry and Trade, Part I, "Factors in Industrial and Commercial Efficiency," H. M. Stationery Office, London, 1927.

RIDGEWAY, WILLIAM, "The Origin of Metallic Currency and Weight Standards," Cambridge University Press, 1892.

ROE, J. W., "English and American Tool Builders," McGraw-Hill Book Company, Inc., 1926.

SCHEEL, KARL, "Elementare Einheiten und Ihre Messung," Handbuch der Phvsik, Bd. 1, Julius Springer, Berlin, 1926.

SCHLESINGER, G., "Über Normung, Typung, und Spezialisierung," Deutscher Normenausschuss, Berlin, 1920.

SCHMIDT, K. H., "Wirtschaftsfragen der Massenfertigung," Georg Stilke, Berlin, 1928.

Smithsonian "Physical Tables," 7th Ed.

State Department (J. Q. Adams, Secretary), "Report Relating to Weights and Measures," Feb. 22, 1821 (16th Congress second session House Doc., 109).

WADE, HERBERT T., "Scales and Weighing; Their Industrial Application," The Ronald Press Co., New York, 1924.

WEBER, GUSTAVUS A., "Bureau of Standards" *Monograph* 35, Institute for Government Research, The Johns Hopkins Press, 1925.

WOODWORTH, J. V., "American Tool Making and Interchangeable Manufacturing," The Norman W. Henly Publishing Co., 1911.

## PERIODICAL ARTICLES

*Annals* of the American Academy of Political and Social Science, "Standards in Industry," May, 1928.

American Institute of Weights and Measures, "Weight and Measure," Serial, Published by the Institute, 115 Broadway, New York.

*Bureau of Standards Yearbook*, 1928, contains a fairly complete bibliography of periodical literature on the general subject of Standardization."

Comité International des Poids et Mesures, "Procés-Verbaux des Séances," Serial, Gauthier-Villars, Paris.

DICKSON, T. C., "X-ray Examination of Metals at the Watertown Arsenal," *Proc. A. S. T. M.*, p. 773, 1924.

HUNKER, W. L., "More Standardization of Railway Supplies is Needed," *Ry. Age.*, Mar. 24, 1928.

KOSHKIN, S. J., "Engineering and Industrial Standardization," *Mech. Eng.*, February, 1927.

MACGREGOR, D. H., "Rationalization of Industry," *Econ. Jour.*, December, 1927.

PORTSMANN, W., "Die Gesetze der Normung," Technik und Wirtschaft, Jahrg. 17, 1924, s. 77 ff.

# INDEX

## A


Abbreviations, 108
Absolute system of units, 27
Acceptable list of approved commodities in purchasing, 134
Accounting methods, 9
Act, Budget and Accounting, 220
Adjustment and Contracts, Interdepartmental Board of, 221, 225
Advance of standardization in industry, 14
Advantages of standardization, 85
of using specifications, 151
Aerodynamic and hydrodynamic tests, 71
Agricultural machinery, 17
products, standardization of, 92
Agriculture, 13
Airplane, 11, 15
Allowances, tolerances and, 118
Alloy, Guillaume's (invar), 36
Alloys and metals, 63
American Association of State Highway Officials, 161
American colonies, 5
American Electric Railway Association, 163
American Engineering Standards Committee, 156, 186, 223
American Gas Association, 163
American Institute of Architects, 163
American Institute of Electrical Engineers, 156, 160, 163
American Institute of Mining and Metallurgical Engineers, 156, 163
American Mining Congress, 163
American Railway Association, 97
Engineering Division, 163
Mechanical Division, 93
American Society for Testing Materials, 158, 163, 183
American Society of Civil Engineers, 156, 163
American Society of Mechanical Engineers, 156, 163
Ampere, international, 51
Ångstrom, 33
Appliances, electrical, and machines, standardized, 10
Application of standardization, 12, 80
Applied psychology, 105
Approved commodities in purchasing, acceptable list of, 134
Arabic numerals, 7
*Arbeitsausschüsse, Deutscher Normenausschuss*, 176
Area, projected, 71
Argentina, 205
Arlington radio station, 47
Armorers, 5
Armour, 7
Army and navy bureaus of medicine and surgery, 54
British, 68
Ordnance Department, 68
Arrows, bows and, 7
Arsenal, Watertown, 64, 66
Art, standardization in, 82
Artist, 4
Asia, 2
Assembly, selective, 84
Associated Factory Mutual Fire Insurance Companies, 163

*Association Française de Normalisation*, 181
Association of American Steel Manufacturers, 163
Association of Governmental Labor Officials, 161
Associations, trade, 114
Assyria, 1
Atom, exploration of the, 58, 59
Atomic energy, 12
  physics, 58
  weights, 59
Atoms, 69
Australia, 155, 205
Australian Commonwealth Engineering Standards Association, 169
Austria, 155
*Ausschuss für Abrechnungswesen*, Germany, 181
*Ausschuss für Arbeitsvorbereitung*, Germany, 181
*Ausschuss für Burowesen*, Germany, 181
*Ausschuss für Lagerwesen*, Germany, 181
*Ausschuss für Symbolik*, Germany, 181
*Ausschuss für Terminologie*, Germany, 181
*Ausschuss für wirtschaftliche Fertigung*, Germany, 179
*Ausschuss für wirtschaftliche Verwaltung*, Germany, 179
Automatic and semiautomatic machines, 14
  lathe, 9
Automobiles, 17

B

Babylonia, 1
Baking, 3
Baldwin Locomotive Works, 54
Barter and exchange, 1
Belgium, 155, 205
Bell Telephone System, 164
Bibliography, 243
Bid bond, construction or supplies, standard government form of, 226
  construction contract, standard government form of, 226
Bidders, instruction to, standard government, 226
Bids, invitation for, standard government form, 226
Blacksmith, village, 4
Board of Trade, London, Standards Department, 34, 164, 192
Bombs and projectiles, types of, 70
Bond, performance, standard government form of, construction or supplies, 226
Bows and arrows and spears, 7
Bronze, Tobin, 39
Brand specifications, 132
Branding of a product, 132
Brands, etc., *versus* specifications, 132
British army, 68
British Engineering Standards Association, 155, 164
British Engineering Standards Association, South Africa Branch, 169
British Engineering Standards Association, New Zealand Local Committee, 170
British thermal units, 49
Budget and Accounting Act, 220
  Bureau of the, 220
Bureau of Chemistry and Soils, 54
*Bureau International des Poids et Mesures*, 187
Bureau of Mines, 161
Bureau of Standards, 24, 31, 54, 161, 194, 205
Bureau of the Budget, 220
Bureau of Weights and Measures, International, 30, 33, 36
Bureaus of Medicine and Surgery, Army and Navy, 54
Bus, motor, 11

Business, recent developments in, 20
Butchering, 3

C

Calorie, 49
Cameras, 58
Canada, 155, 205
Canadian Physical Laboratory, 170
Canadian Research Association, 170
Canal, Panama, 222
Canals, 15
Canning of food, 3
Capital charges, 22
Carpets and rugs, 3
Cartwright's power loom, 6
Castings, soundness of, 66
Centimeter, 30
-gram-second system, 27
Central Chamber of Weights and Measures, 190
Central Electrical Laboratory, 193
Certification of weight and fineness of metallic money units, 2
Chaldea, 1
Chamber of Commerce, United States, 114
Changeability of parts of machines, 5
Charges, capital, 22
Chemical composition, 59
energy, 12
*Chemisch-Technische Reichsanstalt*, 198
Chemistry Division, Bureau of Standards, 202
Chemistry and Soils, Bureau of, 54
Classification of men as to mental characteristics, 105
of standards by use, 95
Clay and Silicate Products Division, Bureau of Standards, 204
Clock, Riefler, Bureau of Standards, 44
Clothing, 1, 3
Coast and Geodetic Survey, 54
defense gun, 16-inch, 65
Code words, 110
Codes, safety, 75
Coinage, 2
Cold, production of, 57
Colonies, American, 5
Colorimeters, 58
Combination, vertical, 20
Combustion, 11
internal, motor, 11
*Comite permanente de Standardisation*, 181
Commerce and trade, five-dimensional arts, 76
Department, 157
Commercial Economy Board, 112
Commercial Standards Group, Bureau of Standards, 204
Commercial transactions, 76
*Commission permanent de l'Association internationale du Congrés des Chemins de fer*, Brussels, 72
Committee on Commodities, Federal Purchase Board, 229
Committee on Economics of Management, German, 179
Committee on Economics of Production, German, 179
Committee on Operations, Federal Purchase Board, 229
Committee on Relations, Federal Purchase Board, 229
Committee on Services, Federal Purchase Board, 230
Committee on Weights and Measures, International, 41, 47
Committees of the Federal Specifications Board, Technical, 241
Commodities, commercial, 224
Commodities, Committee on, Federal Purchase Board, 229
interchange of, 23
testing for compliance with specifications, 135

Communication and transportation facilities, importance of, 15
Compass, 7
Competition, 141
Compliance with specifications, commodities should be tested for, 135
Component, standard, 118
Composition, chemical, 59
Compressed Gas Manufacturers' Association, 163
Compulsory Standardization, 81
Conclusions in regard to the formulation of specifications, 146
Conservation Division of the War Industries Board, 112
Consolidations in industry, 19
  simple industrial, 20
Constants, standard, 24, 55
Consumer, 13
  ultimately pays the bill, 115
Contracts and Adjustments, Interdepartmental Board of, 221, 225
  standardized, 225
Control, management, 9
Coolidge tube, 66
Cooperation in the selection of master specifications, 242
Coordinated effort, 22
Coordination and standardization of government purchases, 220
  of purchase activities, 231
Coordinator, chief, 220
  for purchase, 231
Cottage period in industry, 4
Council of National Defense, 112
Credit, mass, 22
Crompton's mule, 6
Current, electrical, unit of, 51
Custom production, 3
  tailor, 4
Customs Service, United States, 54
Cutlers, 5
Cutting tools, 9
Czechoslovakia, 155

D

Dangers in overstandardization, 85
Data, standard, 211
Day, sidereal, 43
  solar, 44
Definitions, 108
Denmark, 155
Density, 56
Department of Agriculture, 161
Department of Commerce, 161, 164
Department of the Interior, 161, 164
Department of Labor, 161, 164
Department, Ordnance, of the army, 68
Department of Scientific and Industrial Research, British, 164
Descartes, René, 107
Designing, streamline, 69
Designs, standardized, 94
Desirability of purchasing on performance, 136
*Deutscher Normenausschuss*, 156, 171
Development of the internal-combustion motor, 11
  of standards of quantity and quality, 210
Developments in business, recent, 20
Devices, standard, 211
Diagrams, 108
Diesel electric railway locomotive, 11
  stationary power units, 11
Difficulties of standardization, 92
Dimensional standardization, 96, 117
Director, Bureau of the Budget, 220
  National Physical Laboratory, 164
Dirigibles, 11, 15
Division of Simplified Practice, Bureau of Standards, 114, 161

Domestic production, 3
Duralumin, 18
Dyers, 5
Dyne, 41

E

Economics, law of, 14
  revolution, 7
  self-sufficiency, 16
  wants, 87
Economy Board, Commercial, 112
  of using standardized purchase specifications, 224
Effort, coordinated, 22
Egypt, 1
Electric current, unit of, 51
  energy direct from coal, 12
  light and power group, 163
  power transmission, 53
  steam and hydroelectric plants, 10
Electrical and mechanical energy, 59
  machinery, 9
  machines and appliances, standardized, 10
Electrical Manufacturers' Council, 160
  pressure, unit and standard of, 51
  resistance, standards and units of, 50
Electricity Division, Bureau of Standards, 200
Electrolysis, 51
Energy, 29, 53
  atomic, 12
  chemical, 12
  electric, direct from coal, 12
  kinetic, 12
  mechanical, 56
    and electrical, 59
  of sunlight, 12
  radiant, 57
  sources of, 11
  thermal, 12
  transformations, 12
Engine, steam, 8
Engines, steam, stationary reciprocating and marine, 8
Engineering, human, 105
Engineering Societies Building, New York, 157
Engineering Standards Committee, American, 223
Engineers, industrial, 20
English units of measures, 2
Epochs, world, important modern, 6
Establishment of metric standards, 29
Evolution, industrial, 3
Excess weight, 18
Exchange, medium of, 2
Exploration of the atom, 58, 59
Explosives, 7

F

Fabricated Production Department, United States Chamber of Commerce, 114
Fabrication, special, 138
Fabrics, weaving of, 3
Facilities, importance of transportation and communication, 15
*Fachausschüsse*, Deutscher *Normenausschuss*, 176
Factory period, 6
Family, 1
Federal Purchasing Board, 221, 227
  Specifications Board, 143, 161, 180, 221, 332
    authority, 223
    organization and procedure, 221
    technical committees, 241
  standard stock catalogue, 110
Federation of British Industries, 164
Filene, Edward A., 218
Finland, 155
Firearms, 7

Five-dimensional arts, commerce and trade, 76
Foot-pound-second system, 28
Footwear, 3
Force, 41, 53, 161
Ford Motor Company, The, 21, 119, 138
France, 155
Freezing or melting points, standard, 50
  points, 56
French-German potash agreement, 96
  government, 54
  Minister of Commerce, 181
  Standardization Association, 181
Furniture, 3
Future, a look into the, 218

G

Gage blocks, Johansson, 120
  precision, 121
Gages, types of munition, 125
Gas-electric railway locomotive, 11
General conference for weights and measures, 188
General Electric Company, 8
General Motors Corporation, 138
General Supply Committee, United States Government, 222
Geodetic, Coast and, Survey, 54
German Committee on Economics of Management, 180
  Committee on Economics of Production, 179
  industrial standards, 177
  -French potash agreement, 96
  National Economic Board, 179
  National Specification Committee, 180
  Standards Committee, 150, 171
Germany, 155
Gilbreth, F., 87
Gilds, 4
Grading rules, 110
Gram-second-centimeter, system, 27
Gravitation, 12
Great Britain, 155
Greece, 2
Goethe, Johann W., 128
Government, French, 54
  master specification, United States, 223
  purchases, standardization and coordination of, 220
  United States, 54
Guillaume's alloy (invar), 36
Gun, 16-inch coast defense, 65

H

Handicraft production, 3, 4
Hargreaves' spinning jenny, 6
Harness, 3
Harriman, N. F., 129
Heat, 56, 57
  and Power Division, Bureau of Standards, 201
  and temperature, units and standards of, 47
  quantity of, 49
  rays of sun, 12
  subterranean, 12
Holland, 155
Hour, kilowatt, 54
Human element in industry, 104
  engineering, 105
Hungary, 155
Hydrodynamic and aerodynamic tests, 71
Hydroelectric and steam-electric plants, 10

I

Idea of perfection not involved in standardization, 79
Imperial standard yard, 34
Importance of standards to the purchaser and consumer, 76
  of transportation and communication facilities, 15
India Railway Board, 170

Individual preference of users, 139
Industrial application of X-rays, 64, 68
consolidations, simple, 20
engineers, 20
evolution, 3
integration, 21
or economic revolution, second, 218
rationalization, 96
revolution, 6, 7, 219
standardization, 82
object of, 86
work, 54
Industry, advance of standardization in, 14
and science, metric system in, 54
consolidations in, 19
evolution of, 1
modern period in, 19
superconsolidation in, 20
Inspection, 231
Inspectors, partiality of, 139
Institute of Naval Architects, 164
Institution of Automobile Engineers, 164
Institution of Civil Engineers, 164
Institution of Electrical Engineers, 164
Institution of Engineers (India), 170
Institution of Mechanical Engineers, 164
Instruction to bidders, standard government, 226
Integration, industrial, 21
Intensive magnitude, 26
Interchange of commodities in trade and commerce, 23
Interchangeability in manufacture, 117
Interchangeable manufacturing, 91, 112
Interdepartment Board of Contracts and Adjustments, 221, 225
Intermembering of parts, 117
Internal-combustion motor, development of, 11
International Acetylene Association, 163
and national standardizing laboratories, 187
ampere, 51
International Association of Industrial Accident Boards and Commissions, 161
International Bureau of Weights and Measures, 30, 33, 36, 187
International Commission on Illumination, 157, 184, 186
International Committee on Weights and Measures, 41, 47, 188
International Electrotechnical Commission, 157, 167, 184
ohm, 50
prototype kilogram, 36
meter, 30
and kilogram, 189
standardizing bodies, 184, 186
body (proposed), 186
volt, 51
watt, 53
Interworking of parts, 117
Invar (Guillaume's alloy), 36
Iron and Steel Institute, 164
Italian State Railways, 72
Italy, 2, 155, 205

J

Japan, 155, 205
Johansson gage blocks, 120
Judea, 2
Jugoslavia, 205

K

Kew Observatory, 191
Kilogram, international prototype 36
prototype, 37
Kilowatt-hour, 54
Kinds of units, 26

Kinetic energy, 12
Knitting, 3

L

*Laboratoire Central d'Électricité*, 193
*Laboratoire d'Essais*, 192
*Laboratoire de Méchanique*, 192
Lathe, automatic, 9
Laundering, 3
Law, Ohm's, 52
  of economics, 14
Laws, 1
Leather and leather products, 3
Leatherworker, 4
*Le Comité des Forges*, 181
*Le Comité des Houillers*, 181
*Le Comptoir sidérurgique de France*, 182
Length unit, 26
  units and standards of, 30
*Le Syndicat des Entrepreneurs de constructions métalliques*, 182
*Le Syndicat des Entrepreneurs de Reseaux et Centrales électriques*, 182
*Le Syndicat des Constructeurs de material de chemins de fer*, 182
*Le Syndicat des Constructeurs de navires et de machines marines*, 182
*Le Syndicat des Industries radio-électriques*, 182
Letters, Roman, as numerals, 7
*L'Union des Syndicats d'Electricité*, 181
*L'Union des Voies ferrées d'interêt local*, 182
*Leviathan*, 18
Light waves, 35
  years, 210
Lincoln automobile, 119
Locomotive, Diesel or gas-electric railway, 11
  works, Baldwin, 54
Locomotives, 17
  steam, 8
Loom, Cartwright's power, 6

M

Machine age, 94
  utility depends upon performance, 72
Machinery, agricultural, 17
  electrical, 9
  modern, 17
Machines and appliances, electrical, standardized, 10
  changeability of parts of, 5
  semi-automatic and automatic, 14
  specialized, 9
Magnalium, 18
Magnitude, extensive, 26
  intensive, 26
Management control, 9
Management, German Board on Economics of, 179
Manganin, 51
Manufacture, 13
  interchangeable, 122
Manufacturing, interchangeable, 91
  standardization in, 122
Marey, E. J., 87
Marine and stationary reciprocating steam engines, 8
Maschinenbau, 175
Mass, 5
  and weight, distinction between, 41
  credit, 22
  production, 11, 22, 82, 83
    definition of, 91
  purchasing, 22
  secondary standards of, 39
  selling, 22
  standards, 41
    and units, 36
  unit of, 26, 29, 36
Master Car Builders' Association, 93
Master Mechanics' Association, 93
Materials, 105
  standard, 211

Matter, 27
Mean solar second, 44
Measurement, standards of, 24
  standard for, 28
  unit of, 28
Measurements, 30
  precision time, 47
Measures and weights, 1
Measures and Weights, International Bureau of, 30, 33, 36
Measures and Weights, International Committee on, 41, 47
  and weights, standard, 23
  units of, English, 2
Meat-food products, 3
Mechanical and electrical energy, 59
  energy, 56
  power, 12
  revolution, 7
Mechanics and Sound Division, Bureau of Standards, 202
Medicine and Surgery, Bureaus of, Army and Navy, 54
Medium of exchange, 2
Melting point, 56
  or freezing points, standard, 50
Men, methods and products, relations between, 104
Mental characteristics, classification of men as to, 105
Merchant Fleet Corporation, 222
Mercury-vapor turbine, 8
Metal cutting, 8
  Monel, 18
  worker, 4, 5
Metallurgy Division, Bureau of Standards, 203
  science of, 9
Metals and alloys, 63
Meter, 28
  international prototype, 30
  national prototype, 31
Methods, 106
  accounting, 9
Metric standards, establishment of, 29
Metric standards, system in science and industry, 54
  of weights and measures, 2
Metrology, 33
"Metropolis," Paramount picture, 94
Micron, 33
Microscopes, 58
Milliangstrom, 33
Millimicron, 33
Milling, 3
Mining, 13
  standardization correlating committee, 160
*Mitteilungen des Deutscher Normenausschuss*, 175
Modern industry based upon standardization, 89
  machinery, 17
  period in industry, 19
Monel metal, 18
Money, 1
  paper and token, 2
  standard, 23
Motion, 53
Motor bus, 11
  development of the internal combustion, 11
  internal-combustion, 11
  -propelled vehicles, 15
  truck, 11
Mule, Crompton's, 6

N

National Board of Fire Underwriters, 163
National Bureau of Casualty and Surety Underwriters, 163
National Bureau of Standards, 31, 54, 161, 194, 205
National Directory of Commodity Specifications, 162
National Electrical Manufacturers Association, 163
National Fire Protection Association, 163

National Institute of Weights and Measures, 191
National Physical Laboratory, 191
National Physico-technical Institute, Germany, 190
prototype meter, 31
National Safety Council, 163
standardizing agencies, 208
bodies, 155
laboratories, early, 190
National Testing Laboratory, France, 192
Navy and Army Bureaus of Medicine and Surgery, 54
Department, 157, 161, 164
Naval Observatory, 47
Nomenclature, standardization of, 102, 108
*Normal-Aichungs-Kommission*, Austria, 190
Germany, 190
Normalization (normung), 96
*Normenausschus der Deutschen Industrie*, 171
*Normung*, Standardization, 96
Norway, 155
Numerals, Arabic, 7

O

Observatory, Naval, 47
Ocean, tides and waves, 12
Office of Weights and Measures, 190
Ohm, International, 50
Ohm's law, 52
Operations, Committe on, Federal Purchase Board, 229
Optics Division, Bureau of Standards, 201
Ordnance Department of the Army, 68, 124
Organic and Fibrous Materials Division, 203
Organization and Procedure, *Deutscher Normenausschuss*, 171
of the Federal Specifications Board, 221
Organizer in industry, 4
Overman Act, 112

P

Panama Canal, 161, 222
Paper money, 2
Paramount picture "Metropolis," 94
Paris, Lyons and Mediterranean Railway, 72
Parry, David, 127
Partiality of inspectors, 139
Pennsylvania System, 138
Period, cottage, in industry, 4
factory, in industry, 6
in industry, modern, 19
Performance, acceptable, 62
standards of, 24, 61
Philosophy of industrial standardization, 103
Phonetic symbols, 1
Phrases, 108
Physics, atomic, 58
*Physikalisch-technische Reichsanstalt*, 190, 198
Planning research, 211
Plants, hydroelectric and steam-electric, 10
Plato, 25
Plug, spark, porcelain, 57
Point, melting, 56
Points, freezing, 56
Poland, 155, 205
Pool, power, 11
Porcelain, spark-plug, 57
Portugal, 206
Power, 53, 57
loom, Cartwright's, 6
mechanical, 12
transmission, electric, 53
units, Diesel stationary, 11
steam turbine, 8
Practice, standards of, 24, 74
Precepts for specification writers, 151
Precision gage blocks, 121
grinding machine, 119

Precision time measurements, 47
Preferences of users, individual, 139
Preferred numbers in simplification, 116
Preparation of specifications, 144
Pressure, electrical, unit and standard of, 51
Principles of scientific purchasing, 129
Printing press, 7
Proceedings, A. S. T. M., 183
Process, machine, 89
Processes, standardization of, 88
Producer, 14
Product, 106
  branding of a, 132
Production, 5
  custom, 3
  department, fabricated, United States Chamber of Commerce, 114
  domestic, 3
  German Board on, Economics of, 179
  handicraft, 3, 4
  mass, 11, 22, 82, 83
  of cold, 57
Products, standardization of, 88
Projected area, 71
Projectiles and bombs, types of, 70
Prototype kilogram, 37
  international, 36
  meter, international, 30
  national, 31
Provisional or tentative standards, 95
Psychology, applied, 105
Public Health Service, 161
  material-testing laboratory, German, 191
Publication of standards, 174
Purchase activities, coordination of, United States Government, 231
  coordinator for, 231
Purchase standards, 60
  to standard specifications results in economy, 137
Purchases, standardization and coordination of government, 220
Purchasing Board, Federal, 227
  mass, 22
  on performance, desirability of, 136
  principles of scientific, 129
  specifications in, 129

Q

Quality specifications, standardization of, 129
  standards of, 23, 24, 59

R

Radio, 10
  audition, 15
  station, Arlington, 47
  wave lengths, 54
Radiant energy, 57
Radiograph, 67
Radiometers, 58
Radiotelegraphy, 15
Railroad Administration, 93
Railway locomotive, Diesel or gas-electric, 11
  steam, 8
  Paris, Lyons and Mediterranean, 72
  tracks scales, control of, 72
  transportation, 13, 16
Railways, 15
  Italian State, 72
Random samples, 148
Rationalization, definition of, 96
  in Germany, 96, 179
  in various countries, 96
Raw materials of industry, 106
Rays of the sun, heat, 12
  visible and invisible, 58

Recent activity in standardization, 209
applications of standardization, 12
developments in business, 20
Reformation, 6, 7
*Reichsanstalt für Masse und Gewicht*, 191
*Reichsausschuss für Lieferbedingungen*, 179
*Reichskuratorium für Wirtschaftlichkeit*, 179
Relation of research to standards and standardization, 211
Relations, Committee on, Federal Purchase Board, 229
Religion, 1
Renaissance, 6, 7
of standardization, 217
Repetition work, 5
Requirements of a specification, 142
Research, planning, 211
relation to standards and standardization, 211
work, scientific, 54
Resistance, 53
electrical, standards and units of, 50
Resistors, 18
Revolution, Economic, 7
industrial, 6, 7
mechanical, 7
Riefler clock, 44
Rifle, Springfield army, 124
Roads, Roman, 7, 15
Roman letters, 7
Roumania, 206
Royal Society of London, 191
Rubber Association of America, 145
Rules, grading, 110
Russia, 155

S

Saccharimeters, 58
Safety-code Correlating Committee, 160
Safety codes, 75
Sample, standard, 60
Samples (standard), brands, trade names, etc., *versus* specifications, 132
taken at random, 148
Saw, hack-, blades, United States Government master specification for, 235
Scales, railway-track, control of, 72
Science and industry, metric system in, 54
Scientific purchasing, principles of, 129
research work, 54
Screw threads, 83
Second-centimeter-gram, system, 27
mean solar, 44
Secondary standards, 50
of mass, 39
Sectional committee procedure, 155
Selective assembly, 84
Selling, mass, 22
Semiautomatic and automatic machines, 14
Service the ultimate test of fitness, 211
United States Customs, 54
Services, Committee on, Federal Purchase Board, 230
Setting up of standards, or standardization, 78
Sextants, 58
Shelter, 1
Shrinking cavities, 67
Sidereal day, 43
time, 43
Simplification, 117
or standardization of variety, 96
preferred numbers in, 116
standardization by elimination, 117
Simplified Practice, Division of, Bureau of Standards, 114, 161
Soap making, 3

Society of Automotive Engineers, 164
Solar day, 44
second, mean, 44
Soundness of castings. X-ray examination for, 66
Sources of energy, 11
Southern Pacific Company, 138
Space, 27
Spain, 206
Spark-plug porcelain, 57
Spears, 7
Special fabrication, 138
-industry committee, 176
Specification for hack-saw blades, United States Government master, 235
form, standard, 143
requirements of a, 142
writers, precepts for, 151
writing a progressive art, 142
Specifications, 60
advantages of using, 151
Board, Federal, 221, 232
organization and procedure, 221
technical committees, 241
brand, 132
conclusions in regard to the formulation of, 146
cooperation in the selection of master, 242
economy of using standardized purchase, 224
in purchasing, 129
National Directory of Commodity, 162
object of, 130
preparation of, 144
quality, standardization of, 129
standard form for, 232
standardization of, 102, 130
tailor-made, 131
United States Government master, 223
*versus* brands, trade names, standard samples, etc., 132
Speech, 1
Speed, 53
Spinners, 5
Spinning jenny, Hargreaves', 6
Sport, standardization in, 82
Springfield army rifle, 124
*Staatliche Materialprüfungsampt*, 191, 198
Standard and unit of electrical pressure, 51
of length, 51
of mass, 36
of time, 43
component, 118
constants, 24, 55
data, 211
devices, 211
for measurement, 28
form for specifications, 232
government form of bid, construction contract, 226
of bid bond, construction or supplies, 226
of invitation for bids, 226
of performance bond, construction or supplies, 226
instruction to bidders, 226
materials, 211
melting or freezing points, 50
money, 23
obsolete, obsolescent, 95
of length, wave length, 35
processes, 211
prospective, 95
sample, 60
samples, brands, trade names, etc., *versus* specifications, 132
specification for, 143
tentative or provisional, 95
time, 44
weights and measures, 23
Standardization, 5, 11, 19, 63, 104, 117
a compromise, 97
a continuing process, 209

Standardization, and coordination of government purchases, 220
and standards, 13
Association, French, 3
bane or blessing, 126
by elimination, simplification, 117
compulsory, 81
cycle, 214
danger of excess, 85
definition of, 78
difficulties of, 92
dimensional, 96
diminishes capital investment, 85
economic importance of, 97
evolution of, 1
field, boundaries of, 208
in art, 82
in industry, advance of, 14
in manufacturing, 122
in sports, 82
industrial, 82
industry based upon, 89
of agricultural products, 92
of dimensions, 102, 117
of fine arts, 209
of nomenclature, 102, 108
of processes, 88
of products, 88
of quality or specifications, 102, 129
of specifications, 130
of standardizing procedure, 208
of variety, 111, 116
by the War Industries Board, 112
or simplification, 96, 102
philosophy of, 103
primarily the setting up of standards, 78
principles of, 217
railroads interested in, 93
recent activity in, 209
applications of, 12
renaissance of, 217
Standardization, trend of, 207
various aspects of, 102
voluntary, 81
Standardized contracts, 225
designs, 94
electrical machines and appliances, 10
Standardizing agencies, national, 208
bodies, national, 155
procedure, standardization of, 208
Standards, 23, 183
and standardization, 13
and units, 28
of electrical resistance, 50
of heat and temperature, 47
authoritative fixing and enforcement, 81
classification of, by use, 95
Committee, German, 156, 171
Department, Board of Trade, London, 34, 190
establishment of metric, 39
evolution of, 1
importance of, to the purchaser and consumer, 76
mass, 41
of length, units and, 30
of mass, and units, 36
secondary, 39
of measurement, 24
of performance, 24, 61
of practice, 24, 74
of quality, 23, 24, 59
of quantity and quality, development of, 210
of the archives, 190
National Bureau of, 24, 31, 54, 161, 194, 205
purchase, 60
secondary, 50
working, 39
Standing Committee on standardization, 181
Station, Arlington Radio, 47
Stationary power units, Diesel, 11

Steam-electric and hydroelectric plants, 10
engine, 8
locomotives, 8
Steamships, 15
Steam-turbine power units, 8
Stoneworker, 4
Streamline designing, 69
Structure, fundamental, of matter, 69
Submarine, 11
Subterranean heat, 12
Sun, heat rays of, 12
Sunlight, energy of, 12
Superconsolidation in industry, 20, 21
Supply Committee, General, 222
Surgery and Medicine, Bureaus of, Army and Navy, 54
Survey, Coast and Geodetic, 54
Sweden, 155
Switzerland, 155, 206
Symbols, 108
phonetic, 1
System, centimeter-gram-second, 27
metric, in science and industry, 54
of units, absolute, 27

T

Tailor, custom, 4
-made specifications, 131
Tanning, 3
Technical Committees of the Federal Specifications Board, 241
Technologists, 59
Telegraph, 10
Telegraphy, 15
Telephone, 10
Telephony, 15
Telepictography, 15
Telescopes, 58
Television, 15
Tentative or provisional standards, 95
standards, A. S. T. M., 183
Temperature, 47
and heat, units and standards of, 47
Tests, aerodynamic and hydrodynamic, 71
The Panama Canal, 164
Thermal energy, 12
units, British, 49
Thermodynamics, 8
Tides and waves of the ocean, 12
Time, 26, 27
division of, 1
measurement, precision, 47
sidereal, 43
standard, 44
unit and standard of, 43
Tobin bronze, 39
Token money, 2
Tolerances and allowances, 118
Tools, cutting, 9
Turbine, mercury-vapor, 8
power units, steam, 8
Turkey, 206
Track, railway, scales, control of, 72
Tractor, 11, 17
Trade and commerce, 23
five-dimensional arts, 76
associations, 114
names, etc., *versus* specifications, 132
Transaction, commercial, 76
Transmission, electric power, 53
Transportation and communication facilities, importance of, 15
railway, 13, 16
Trend in quality standards, 218
of standardization, 207
Tresca, M., 30
Truck, motor, 11
Tube, Coolidge, 66
Turbine, steam, power units, 8

Twentieth Century Limited, 18
Type standardization (typung), 96
Types of munition gages, 125
Typung, type standardization, 96

U

Underwriters' Laboratories, 163
Union Pacific System, 138
Unit and standard of electrical pressure, 51
of time, 43
length, 26
of electrical current, 51
of mass, 26
of measurement, 28
United States, 155
Chamber of Commerce, 114
Customs Service, 54
government, 110
master specifications, 223, 235
for hack-saw blades, 235
Independent Telephone Association, 164
Steel Corporation, 138
Units, absolute system of, 27
and standards, 28
of electrical resistance, 50
of heat and temperature, 47
of length, 30
of mass, 36
British thermal, 49
kinds of, 26
of measures, English, 2
Unlimited variety expensive for consumers, 115
Utility factor, 207
net, 61
of a machine depends upon performance, 72

V

Variety, standardization of, 111, 116
by the War Industries Board, 112
Variety, unlimited, expensive for consumers, 115
*Verein deutscher Ingenieure*, 171, 172, 175, 179
Vertical combination, 20
Volt, International, 51
Voluntary fixing of standards, 81
standardization, 81

W

Wants, economic, 87
War Department, 157, 161, 164
War Industries Board, 112
on waste, 219
Waste, war on, 219
Waterfalls, 11
Watertown Arsenal, 64, 66
Watt, international, 53
Wave-length standard of length, 35
lengths, radio, 54
Waves and tides of the ocean, 12
light, 35
Weavers, 5
Weaving of fabrics, 3
Weight and mass, distinction between, 41
excess, 18
Weights, 41
and measures, 1
Division, Bureau of Standards, 200
International Bureau of, 30, 33, 36
International Committee on, 41, 47
standard, 23
atomic, 59
Western Electric Company, 138
Whitney, Eli, 6
Winds, 11
Woodworker, 4
Woolworker, 4
Work, industrial, 54
repetition, 5
scientific research, 54

Work, value, 207
Working or general committees, 176
Works, Baldwin Locomotive, 54
World Economic Conference, 96
  epochs, important, 6
Writing of specifications a progressive art, 142
  picture, 1

X

X-Rays, industrial application of, 64, 68

Y

Yard, 28
  imperial standard, 34
Years, light, 210

530.8 H29

a39001 0069637336

530.8
H29

Due 24th.

731

76019 67